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INDUSTRIAL ADMINISTRATION

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The future of civilized government and even, I think, of civilization itself rests upon our ability to develop a science and a philosophy and a practice of administration competent to discharge the public functions of civilized society.

From The Role of Administration in Government by Charles A. Beard, in "The Work Unit in Federal Administration," Public Administration Service, Chicago, 1937, p. 3.

We aim at a life beautiful without extravagance and contemplative without unmanliness; wealth in our eyes is a thing not for ostentation but for reasonable use, and it is not the acknowledgement of poverty that we think disgraceful, but the want of endeavor to avoid it.

From Pericles's funeral oration for the Athenian soldiers who fell at the battle of Marathon (490 B.C.*). Quoted by Frederick W. Taylor at the First Amos Tuck Conference on Scientific Management, Dartmouth College, Hanover, N. H., 1911.*

Preface

During the past decade a very perceptible change has taken place in the concept of the type of man presumed to be best suited for upper-level industrial management. Many analyses have been ventured on the subject of what attributes such a paragon should possess. Invariably the conclusions of these studies stress that tomorrow's effective manager must have a broader background resting heavily on a cultural-philosophical base. The ideal manager must be a composite doer-thinker who can devise better products and more effective methods. At the same time he must be able to convince all concerned that his is a good and progressive organization.

Among the reasons for this growing stress on the cultured, capable, broad-background manager is the rather recent and sudden realization that our industrialists are more than ever acceptable in practically all our social strata, even at the very highest levels. This acceptance follows the attainment of professional status by some members of the industrial management group. Probably even more important is the widespread recognition that our nation's continued economic progress is directly related to the caliber of our industrial leaders. This recognition has been accompanied by proportional rises in management income levels. Social acceptance for these and other reasons means that top-level industrial managers must mingle with leaders from other areas of activity. Competitive pressure dictates that the leaders from business and industry be qualified to hold their own when in contact with these intra- and extra-industry associates.

Other factors, such as the increasing complexity of modern industry, make mandatory the need for what has sometimes been termed the integrative generalist. Unfortunately, the stress on broad background, the "generalist" rather than the "specialist," has often led to serious misinterpretation. In some instances technological competency has been assumed to be a serious handicap to advancement into the management sphere. The specious reasoning for such argument rests on the assumption that a technically qualified individual has only narrow interests and can never develop into a broad-background manager. Such contentions are not only erroneous, they are ludicrous. A basic premise of this text is the belief that no man can become an effective manager without first mastering competency in some specific technical or functional area in industry. It is only in such a capacity that the managerial candidate will have an opportunity to discover and to develop his managerial potential.

This does not mean that every would-be manager must undergo a formal business-administration or engineering schooling. The learning process is not restricted to the university. Actually, much of the technical grooming, and even more of the broader comprehension, can best be acquired only at the actual scene of operations. The function of a formal program, such as a course in basic management principles and practices, is to short-cut the learning process by condensing experience, by presenting the more meaningful situations, and by facilitating the acquisition of the requisite ideas and technical vocabulary in a systematic fashion.

The basic purpose of this text, then, is to help condition management candidates so that they will recognize the importance both of actual performance and of management concepts. Performance is the technological factor dealing with the "how to" aspects and is viewed almost exclusively in physical terms. Concepts, however, are philosophical components concerned with the "why" underlying specific courses of action. Whereas a technology represents a way of doing, a philosophy is a way of thinking. Management, then, deals not only with the organization of physical means of production, but even more importantly, with the conditioning of men's minds. It is extremely important for effective organization that the modern industrial manager be both a mechanic and a molder of minds.

This text rests upon several important premises relating to the type of man who will be tomorrow's industrial leader. It is suggested that the following qualifications are necessary in a future leader of industry:

1. He must possess all the attributes associated with the professional man.

2. He must develop his potential continuously as long as he is part of the management group.

3. He must master competency in at least one specific, and even narrow, technical or functional area.

4. He must acquire a broad cultural-philosophical background in addition to his formal training and his technical experience.

5. He must learn to view his functional areas and all others as important but subordinate adjuncts in the over-all organization.

Analogous to Plato's philosopher-kings, the future dominant force in our industrial society will be the administrator who combines the better qualities of the philosopher and the technician.

The stress on both concepts and techniques leads logically to a division of the text into two relatively homogeneous sections. Part One might be viewed as a conceptual analysis of the broader aspects forming the foundation and framework of industry. Part Two is the technical analysis describing the more commonly used industrial management methods. In order to facilitate this dual presentation, a rather rigid pattern will be followed. This pattern consists of the following sequence:

1. Definition and Description
2. Development
3. Corollaries and Related Aspects
4. Significance
5. Illustrations

Although this structural form will be common to the first ten chapters, intensive and extensive analysis will necessarily vary. Likewise, as is explained at the end of Part One, a slight change is necessitated in the chapter structure in Part Two by the basic differences between concepts and practices.

Since this is presumed to be a basic text, there is an obvious inference that depth of analysis in respect to any single concept or technique must necessarily be limited. Even the very number of concepts and techniques must be kept at a minimum. Consequently, certain very important adjuncts of industrial management, such as the financial factors, accounting procedures, marketing practices, engineering functions, and personnel principles, will not be analyzed in detail. Inclusion of these and other related topics would result in either an encyclopedic work or an extremely superficial study.

It is assumed that the student using this text has acquired, from

his secondary-school education and from his current reading and contact with business, a fund of knowledge relative to industrial administration. This body of ideas and facts, while it varies considerably from individual to individual, does provide a base, however tenuous. Following this assumption, a conscious effort is made to avoid the trite and elementary practice of defining and describing every term as it appears in the text. Since the basic objective of the text is to help the interested student comprehend the fundamental concepts and techniques of industrial management and to develop a facility of expression in respect to these concepts and techniques, the terminology used will be somewhat advanced beyond the elementary level. This follows also from the conviction that the full scholastic potential of many of our better students is not utilized simply because the challenge is inadequate.

It is hoped that through this text the student, whether majoring in industrial management, in any other phase of business administration, or in a nonbusiness subject, will get a better perspective of business and industry in the broader social reference. On the one hand, he should recognize that business and industry are neither mundane, prosaic, degrading, or soul-destroying. On the other hand, industrial pursuits are probably no more complex, challenging, or rewarding than other areas of endeavor.

Typical of any dynamic field, industrial organization is in a state of flux, with progress ever in the direction of more complex techniques, more intricate mechanisms, higher-caliber labor, a greater variety of better products, and, it is hoped, a greater satisfaction on the part of all concerned. The maximizing of this satisfaction, through more effective organization, requires a keener awareness, a more refined sensitivity to all pertinent aspects. A higher order of awareness and sensitivity can come only from self-development through use of available means. This text, it is hoped, will provide a means for such self-development.

Stanley Vance

Contents

PART ONE

Concepts

CHAPTER 1

The Concept of Management

DEFINITION AND DESCRIPTION

The concept of management is universal and as old as the human race. In essence, management is simply the process of decision making and control over the actions of human beings for the express purpose of attaining predetermined goals. There are at least five basic ingredients in the managerial process: (1) deciding on a course of action, (2) obtaining the necessary physical means, (3) enlisting others to assist in the performance of the requisite tasks, (4) seeing that the job is properly accomplished, and then (5) apportioning the product of the joint venture. This broad definition applies not only to the economic sphere but to every human activity whenever the efforts of two or more individuals are combined to perform a task. The conductor of a symphony orchestra, the producer of a television program, and the coach of a football team are equally as deserving of the title of manager as is the executive of a manufacturing enterprise.

Management: An Instinct. The antiquity and universality of the urge to manage logically leads to the inference that management is basically a psychological process. As such, it could be classified as an instinct. An instinct is an innate impulse, an inborn pattern of activity and response common to a given biological stock. The importance of intuition, of foresight, and of similar attributes in decision making gives credence to the contention that management flows from inner impulses. It follows logically that if the ability to manage were ex-

clusively a biological function, then superior managers could be developed by strict adherence to the principles of eugenics. The false notion that heredity alone was responsible for leadership ability was the basis upon which aristocracies were founded. Even today, the erroneous belief that some individuals are born to be leaders persists, at least implicitly, in certain areas. This is partly the case in business when managerial succession is determined solely on the basis of family ties or personal friendship. A great majority of progressive businessmen today do not believe that leadership talent must inevitably gravitate to the top of an organization by chance or instinct alone. The tremendous waste of such a managerial-development process is obvious.

On the other hand, many authorities maintain that there is a positive correlation between certain physical types and managerial success. These beliefs become more acceptable if they are tempered with the understanding that an individual's physical make-up is the mechanism requisite for both mental and bodily activity. Glandular deficiencies, organic disorders, and in fact any ailment can impair performance. Thus it is evident that a sound body, activated by a sound mind and keen instincts, is essential for the performance of any human activity, including that of managing. However, management itself is not exclusively a biological function.

Management: An Art. In addition to instincts, management depends upon the mental faculties. As was stated previously, management consists in deciding what is to be done, securing the necessary ingredients, enlisting others to lend their efforts, coordinating the various components, and finally apportioning the benefits accruing from the combined endeavor. These decision-making and decision-activating functions—planning, procurement, staffing, control, and performance evaluation—depend upon the manager's ability to exercise judgment and volition. The importance of judgment and volition in decision making elevates management to the status of an art. Although it is not classified among the fine arts, such as music, painting, and sculpturing, management is nevertheless a true art in both the creative and applied sense. Management qualifies for this designation since it is a way of doing things through the application of rules and principles developed out of experience. It is the function of the arts to get things done through deliberate effort. Situations which in all probability would not come about by chance are carefully arranged. Acquired know-how, then, is applied to produce the desired results.

Management as an art must be developed by the individual through intensive training. An artist, in the conventional sense of the term, brings his talents to fruition only through long and arduous endeavor.

Even a genius, such as Wolfgang Amadeus Mozart, who wrote songs at the age of five and composed an opera when he was only nine years old, had to apply himself almost constantly to his music. The virtually complete withdrawal of most successful writers, musicians, painters, and other creative artists from extraneous activities, together with an intensive concentration on their art, is probably the most vital factor in their success. There is considerable truth in the aphorism: "Genius is 90 per cent perspiration and only 10 per cent inspiration." This stress upon management as an art leads to the conclusion that an individual possessing keen managerial instincts must carefully cultivate his attributes if he aspires to lead men. One of the objectives of this text is to help the interested student develop these necessary attributes through an analysis of the principles and practices which comprise the art of management.

Management: A Science. In addition to viewing management as an instinct and as an art, it is imperative that modern management should also be considered a science. In general, a science is a branch of knowledge dealing with a body of facts systematically arranged and showing the operation of general laws. The objective of any science, including that of management, is to replace guesswork with exact knowledge so that worthwhile goals can be reached with a minimum expenditure of time, effort, and cost. This conservation of energy is accomplished by a careful study of cause-and-effect relationships, measured numerically whenever possible. The importance of measurement as the basis for the scientific method was succinctly set forth by Lord Kelvin.[1] "I often say that when you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of meager and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely, in your thoughts, advanced to the stage of science, whatever the matter may be." The scientific method is sometimes called the research or experimentation method since it rests upon the collection, classification, and correlation of large masses of pertinent data. Out of the analysis of these data conclusions are logically drawn and then corroborated through application. Generally this scientific sequence results in the establishment of standards, formulas, rules, or even laws, which can be used as guides to future action.

Scientific management should be distinguished from the very prevalent practice of systematic management. The latter is the product of

[1] Quoted in *Quality Control and Research,* Scientific Apparatus Makers' Association, Chicago, p. 1.

know-how acquired through the process of trial and error, with the work place usually serving as the laboratory. Out of the resolving of pressing problems, there normally develops an accepted behavior pattern which can be termed a system. Practitioners of the systematic method frequently respond to stimuli with a sort of reflex action, much in the manner that Pavlov's dogs, once their reflexes were properly conditioned, reacted automatically to stimuli. While it is true that such response, based largely on accepted behavior patterns, is far more desirable than an outright hit-and-miss approach, the inflexibility of the systematic method frequently results in managerial ultraconservatism and even in retrogression. There is also the possibility that the trigger mechanism in the conditioned-reflex type of management can easily lead to confusion when changing circumstances alter cause-effect relationships. For example, a number of industrial concerns, including Montgomery Ward Company, adopted a wait-and-see policy after World War II in the firm conviction that history would repeat itself. They reasoned that the economic cycle which accompanied World War I must inevitably develop out of every major war emergency. Thus a post-World War II depression was assumed to be inevitable. When the anticipated full-fledged depression did not materialize during the next dozen years, the overcautious corporations were found lagging behind their more optimistic and more aggressive competitors.

It is obvious that there is tremendous social, psychic, and economic value in the application of the scientific method to industry. Hit-and-miss techniques and even systematic management are superseded by a method which provides a relatively higher degree of accuracy in prediction than can be obtained from the older management methods. This improved predictability results in the attainment of objectives with a decreased expenditure of energy, time, and cost.

Among the more important components of scientific management which assist in attaining a high degree of accuracy in prediction is the theory of probability. Basically this theory aids in determining the relative frequency, in the long run, that a given event will occur under a set of controlled conditions. Thus the theory of probability makes possible the measurement of uncertainty in quantitative terms. With this statistical tool, prediction is facilitated and decisions can be made in a rational manner. Because of its importance, the theory of probability will be discussed in greater detail in subsequent chapters.

Management of Industrial Enterprises. Thus far management has been considered in its generic sense. This over-all appraisal has some

merit in so far as it focuses attention upon those aspects of management which are common to all forms of group activity. Yet such an eclectic appraisal has serious limitations. Management in the generic sense is essentially a hypothetical concept. In practice, management is always concerned with a specific area of activity. As society becomes more complex, these areas of activity become more numerous and more highly developed. Thus many forms of management which are today the subject of serious study were only a few decades ago practically unknown. The roster of these relatively recent additions to the management family includes such specialized activities as municipal management, hotel management, hospital administration, and many others. This recognition of the many highly developed areas in which management plays a paramount role makes it mandatory that any meaningful analysis of management be restricted to a single specialized field. Consequently, this text will consider chiefly the development and application of managerial concepts as they pertain to human endeavor in the economic sphere. In particular, major emphasis will be given to the management of manufacturing enterprises.

Industrial Enterprise. It has been stated previously that management is concerned with the accomplishment of tasks through united effort. In the economic sphere this joint endeavor is concerned with the output of goods and services which have want-satisfying characteristics. It is this desire to satisfy human wants which initiates the chain of actions that lead to industrial endeavor. When an object has the power of satisfying a human want, it is said to have utility. Economists generally designate five major kinds of utility: (1) form, (2) time, (3) place, (4) possession, and (5) service. The chief function of manufacturing industries is to create form utility. In this respect industrial management might be defined as the efficient combination of productive factors for maximizing the creation of form utility.

An ordinary textbook is an excellent example of how managerial decisions lead to the modification of an object's form from a possibly useless item to a considerably more useful good. Some time ago the paper for this text was made from the cellulosic substance of coniferous trees. These evergreen trees, growing in some sparsely inhabited region, had utility only in so far as they provided some scenic beauty and helped in preventing erosion. Then a manager of sorts concluded that these specific trees were ready for processing. The trees were cut down, taken to the paper mill, and reduced to pulp. After many intermediary steps, the final product—book paper stock—was ready for marketing. Eventually, after many more managerial decisions, the substance of the coniferous trees, its form radically changed by industrial processing,

was made into a textbook. In their natural form the raw materials used in making the text were probably worth only a few cents. Changing the form of the raw materials resulted in a tremendous increase in utility and in value added.

The concept of value added, described in greater detail in Chapter 3, is probably the best single index of the effectiveness of any given industrial enterprise. Value added represents the utility created by the actions of a specific management. Value can be defined as the power of a good to command other goods in exchange. In the manufacturing process, value is added to the raw materials chiefly through the contributions of manpower and machine power in the modification of the raw material's form. The greater the relative value added, the more that specific enterprise is contributing to our economy. Consequently, it is vital that industrial managers not only select the best factors of production but employ the most efficient technology and make products that are in demand. The decisions which led to the timbering of the coniferous trees, and thence to the publishing of this textbook, might foreseeably have been supplanted by alternative decisions. For example, the timber might have been converted into lumber for the construction, furniture, or packaging industries. Even if the logs had been sent to a pulp mill, it was still possible to process the pulp into a form other than book stock, and even into a nonpaper product such as rayon. Then too, at the very beginning of the decision-making process the managers could have decided that this was not the appropriate time to cut the trees.

The purpose of this illustration is to emphasize the basic function of industrial management—the creation of form utility through judicious combining of the basic ingredients of production: manpower, mechanisms, and materials, with adequate attention being given to money, markets, and methods. Good judgment in the selection, combination, and evaluation of these factors is conducive to efficient industrial management.

Industrial Management: A Specialized Field. While the basic principles of management are applicable to any activity where human beings cooperate to accomplish predetermined objectives, it must not be assumed that a training in one sphere of management qualifies an individual for immediate and efficient performance in all areas of management. While it is true that there are instances where an individual proficient in one field, for example, government administration, might successfully apply his talents in a totally different field, such as industry, these cases are exceptions rather than the rule. For example, soon after World War II, there was a noticeable influx of retired

military leaders into industrial executive positions. Even though most of these military leaders were undeniably outstanding in their profession, it appears highly probable that they were named to top executive positions in industry chiefly for publicity and contact value. It should be conceded that transference of leaders from one sphere of activity to another sphere can occasionally be accomplished successfully. Such a practice, however, has serious limitations. One of the chief factors which militates against the facile movement of managers from one area to a totally different area is the steadily increasing complexity of specialized industrial techniques. Although it is obvious that the manager will not himself always be called upon to apply specific industrial techniques, he invariably must know how and when to authorize their use. Then too, it is the manager who must follow up and evaluate the application of techniques. It would seem ludicrous if leadership in industry were expected to be effectively assumed by individuals having no intimate knowledge of a specific industry's problems, practices, policies, and philosophy.

As industry expands and as technological progress continues, it becomes more and more imperative that our industrial leaders be technically proficient. This stress on competence makes it mandatory that an aspirant to a managerial position in industry be well versed not only in basic management principles but also in the more specialized concepts, tools, and techniques of industrial management. The importance of a formal training in the principles and practices of industrial management for would-be managers and administrators has sometimes been overlooked for a number of reasons. First, the field has only recently been developed; thus many of the older generation of industrial leaders had little opportunity to become formally acquainted with the recent innovations. Second, the rapid economic expansion during the past two decades created a serious imbalance between the supply of and demand for managers at all levels in industry. Lack of trained industrial management specialists forced many concerns to hire large numbers of what might be termed nonprofessionals. It should be pointed out that in some instances these nonprofessionals, realizing their shortcomings and the magnitude of the job, raised their proficiency by a diligent program of self-improvement.

Another limiting factor which should be recognized is the improper application of some of the techniques when first introduced. To illustrate this point: serious harm was done to the development of scientific industrial management by the influx of self-styled efficiency experts during the 1920s. One consequence of the exaggerated claims, the failure to recognize limitations, and the outright bungling by

charlatans and incompetents was the deep distrust of most workers and many management representatives of "efficiency expertism." Similar repercussions, although to a lesser degree, have resulted from sudden projection into the limelight of job evaluation, employee testing, arbitration, automation, predetermined times, operations research, etc.

In summary, the need for closer focusing of attention upon the specific concepts and techniques employed in modern industrial management seems apparent. The first step toward improvement in this area is to differentiate between management in the generic sense and management as it applies to industrial enterprise.

DEVELOPMENT

The development of concepts is inextricably meshed with economic history. Since it is not the primary objective of this text to give a detailed historical account of management evolution, the sections dealing with the concept's development will necessarily be rather condensed. The interested student can readily refer to economic-history textbooks for more detailed information.

The relative insignificance of industrial production in most ancient civilizations can be inferred from the very lack of documentary evidence. Trade, both domestic and foreign, received far more attention from the ancient scribes than did manufacturing. Yet even the allusions to commercial activity are relatively fragmentary.

Students of Egyptology seem to be in agreement in stating that even prior to 3000 B.C. there was a relatively large industrial population in the larger communities then flourishing along the Nile. Craftsmen attained a high degree of artistry and technical skill in metalworking, textile processing, tanning, masonry, and in a variety of other occupations. Although slave labor was used extensively, the craftsmen were predominantly free and members of the middle class. Rigid state control of an extreme bureaucratic type extended into every facet of economic activity. Under such repressive conditions Egyptian industry never really flourished, and the problems, principles, and practices of management in industry remained in an incipient stage.

The Code of Hammurabi, written around 2000 B.C., clearly indicates the importance of commerce and industry among the Babylonians. A pristine factory system came into being when the Babylonian temples were made the centers of industrial activity. Well-organized central workshops were set up within the temples where priest-craftsmen supervised operations in such varied occupations as brickmaking, brewing, weaving, and baking. In addition to these early factories, a "putting-out" system of production was also widely used. In the putting-out

process work was performed in individual homes on consignment from contractors who supplied the raw materials and periodically collected the finished goods. Both these production systems, putting-out and centralized work shops, were to become important components of the industrial revolution nearly 4,000 years after the Babylonians effectively employed both techniques.

Among other industrial practices which prevailed in Babylon were an elaborate apprenticeship system, a rigidly regulated wage scale, and a carefully prescribed contractual procedure for making deeds of settlement, partnership agreements, wills, house leases, and many other legal decisions. Each craft was held strictly accountable for the quality of the work put forth by its members. In respect to interest on loans, there was a surprisingly modern attitude. Interest rates, although regulated by law, were rather high, 20 to 25 per cent, presumably because capital was scarce and risks were great.

The Babylonians had a real money economy even though coinage of money was not introduced until much later, at about 800 B.C., in what is modern Turkey. Among the Babylonians both gold and silver, in bulk or in bars, served as standards of value with an exchange ratio of about 15 portions of silver to 1 portion of gold. Of even greater importance to the development of industry was the introduction by the Babylonians of the concept of commercial paper. In this respect the Babylonians were far ahead of all other ancient economies. Actually, Western Europe did not make comparable progress until the beginning of the commercial revolution in the sixteenth century.

Practically every other nation of the ancient world engaged, in varying degrees, in both industry and commerce. In Phoenicia the importance of trade led to the control over that seafaring nation by a commercial oligarchy. Even at the height of the commercial revolution in England and Western Europe, nearly 2,500 years later, the leaders in industry, commerce, and finance never attained a level of importance in national affairs comparable with that bestowed upon Phoenician merchants.

The ascendancy of the Greek city-states was closely correlated with the development of commerce and industry. The paucity of raw materials, and particularly of food, in most of Greece made trade imperative. Attica, since very early times, could grow only enough grain to feed about half its population; consequently, imports were necessary. The intense commercial rivalry which followed inevitably led to outbursts of hostility.

Industry in ancient Greece was restricted to rather small shops

normally employing fewer than 20 workmen. The largest Athenian plant, an armory making shields, employed only about 120 men in wartime. Worker training consisted of a well-developed apprenticeship program. Specialization as to occupation, and even in tasks, was common. For example, in the making of sandals, one worker cut the material while another did the sewing. The ceramics trade even advanced through task specialization into mass production. By using molds both to form the vase and to impress the decorations, the Athenians successfully experimented in the mass production of the renowned Megarian bowls. It should be noted that generally the specialized tasks were performed by slave labor.

Although returns on industrial enterprise ranged between 25 and 30 per cent, Athenian workmen did not appear interested in increasing their scale of operations. A lump-of-labor philosophy prevailed, and as a consequence, workmen limited output according to purchase orders actually received. There was very little production in anticipation of future demands.

The Greek views on commerce and industry ran to extremes. Spartans were forbidden by their laws to engage in manual labor. Most Greek intellectuals looked upon labor as being dishonorable. Aristotle was especially emphatic in his condemnation, maintaining that manual labor and commerce destroyed the higher virtues. Plato was similarly severe in his condemnation, maintaining that those who produced goods by their labor should receive in payment only the consciousness of serving the commonwealth and a share in its life. As a consequence, most industry and commerce were performed by metics, a class of resident aliens who were not permitted to own land, and thus were forced into the less honorable pursuits. Yet many Greeks, particularly Socrates, extolled the merits of manual work, done in moderation.

Probably the chief factors accounting for the antipathy of the Greek philosophers toward work and business were (1) the extent to which trade was concerned with luxury items, (2) the reliance upon slave labor, and (3) the preoccupation of the philosophers with metaphysical musings. The chief cause for Athens' decline in commerce between the years 260 and 229 B.C. was the unwillingness of its merchants to assume substantial business risks in the face of political uncertainty and disorganization which existed during the Macedonian domination. With the decline in commerce, there came a marked deterioration in craftsmanship, so that competitors easily captured Athens' former markets.

With the expansion of the Roman Empire, a new emphasis was

placed upon commercial intercourse. The tremendous flow of goods as tribute into Rome from all corners of the Empire was a great stimulus to trade. However, aristocratic aloofness soon manifested itself in a series of decrees prohibiting senators and other high-placed Romans from dealing in foreign trade. From the close of the second century B.C. most commercial and industrial activity was carried on by foreigners and freed slaves.

Manual labor was held in very low esteem. The abundance of slave labor resulted in practically all production being relegated to slaves. As one consequence of the plentiful supply of slaves, there was no inducement for mechanical ingenuity or economy of labor.

The Romans, noted for their organizing ability, did apply their talents in a systematic exploitation of economic ventures. There developed in Rome a class of wealthy businessmen who formed the equestrian order. These equites, or knights, had movable or liquid capital as contrasted with the landed gentry. The equites frequently banded together to form joint-stock companies, called *societates publicanorum,* for handling state-controlled business such as the operation of mines and plantations and the collecting of taxes. These Roman joint-stock companies, although in a few respects similar to our modern corporation, could not carry on private business activities. Such ventures were left to another category of equestrians, called *negotiatores,* who were forbidden to form joint-stock companies. Thus, although some historians infer that the *societas publicanorum* was the forerunner of the corporation, a closer study indicates very little similarity. Actually the Romans can be termed second-rate as financiers and industrial enterprisers, having very little comprehension of the importance of productive capital, of profit as a legitimate reward for enterprise, of technological advancement, or of labor as a factor of production.

The decline of Rome further delayed the evolution of business and industrial management. The feudal economy of the Middle Ages, with its stress on the self-sufficiency of every household and every minute principality, gave very little inducement to either trade or industry. The revival of Greek learning, particularly of Aristotle's philosophy, led to a most emphatic condemnation of all types of business endeavor except that which centered at the local level. Local trade and production monopolies in the guise of guilds developed on a large scale during the twelth century. Among the functions of these guilds were:

1. Regulation of wages
2. Fixing of prices and conditions of sale
3. Determination of hours and conditions of labor

4. Control of workmanship and quality of materials
5. Restriction of entrance into the trade by means of a systematic apprenticeship
6. Settlement of disputes among members
7. Providing social and fraternal activities for guild members

With the breakdown of the feudal system in the sixteenth and seventeenth centuries, mercantile activity took on a more favorable aspect. The era of discovery opened up new trade routes and new continents. Precious gems and metals became available in previously undreamed-of quantities. Commodities which formerly had been scarce luxuries reserved for the monarch and his cohorts were now offered in quantity to the upper middle class. Hundreds of new products, gathered from the far corners of the world, appeared in the market place.

The quickening tempo of trade was assisted by a reversal in the popular abhorrence of moneylending. Usury had been condemned by most ancient people. Demosthenes emphasized that the Athenians hated usury since the most common reason for borrowing was to pay for extravagant living. Yet Demosthenes stated that usury was a common practice indulged in by most rich Athenians, who thereby increased their incomes substantially and with little effort. This double standard was also practiced by the Romans, who, however, differentiated between a *commodatum,* a loan for assisting a needy individual in buying items to be used for production purposes, and a *mutuum,* a loan expended in consumption.

Until the middle of the sixteenth century, usury was punishable by the most severe penalties. Gradually, lending became accepted as a necessary evil, and by the end of the sixteenth century, the concept of "interest" as a legitimate charge for the use of money began to replace the odious term "usury."

With the increased availability of capital funds, the legitimatizing of interest, and the acceptance of the merchant as a provider of services to the community, the way was set for the commercial revolution. Once the public's latent appetites were discovered, new sources of marketable goods had to be found. Beginning probably in the late seventeenth century and gathering momentum through the eighteenth century, the attempt at increasing the supply of wanted commodities by intensified handicraft production developed into what is popularly known as the Industrial Revolution. With this significant production change came a set of new managerial concepts, principles, and techniques. Necessity was the mother of these innovations. Previous

economies had depended upon slaves, helots, plebeians, serfs, and similar low-status laborers for the production of needed commodities. However, the managerial methods commonly applied to slave labor could hardly be used effectively with the new type of industrial wage earner. Considerable managerial skill and attention also had to be focused upon the productive equipment, steadily increasing in quantity and complexity. The growth in scale of operation made mandatory the installation of better accounting practices. The growing need for capital funds led to the development of new principles and practices in the field of finance. Attempts at improving the movement of goods to the market, and thence to the consumer, had similar effects in the area of distribution. Thus, through an evolutionary process whose beginning cannot be precisely identified, modern industrial management slowly came into being.

COROLLARIES

The relationship of concepts to corollaries is quite similar to the enigmatic "Which came first, the chicken or the egg?" In most dynamic situations there is probably no clear-cut differentiation as to priority between cause and effect. It is more likely that a reciprocal relationship exists, so that a modification in one component induces changes in the other parts. Consequently, the so-called corollaries which will be presented in this and in subsequent chapters should not be considered as having been originated by the concepts; nor are the corollaries exclusively concerned with the specific concepts.

COROLLARY 1. The Free-enterprise System

Industrial management principles and practices can function only within the framework of an economic system. It is reasonable to assume that management principles and practices will be conditioned to a very large extent by the type of economic system which prevails. For example, the concept of authority would have quite different interpretations in a planned economy and in a free-enterprise system. It is interesting to note that the transition from feudalism to mercantilism, then to a laissez-faire capitalism, and finally to the current economic systems has not followed identical paths in all modern industrial nations. For this reason it is sometimes rather perplexing when we try to transplant management principles and techniques which have proved to be successful in this country to other nations. The inability of many foreign so-called free enterprisers to comprehend and adapt these principles is almost congenital. Lacking the economic climate,

the tradition, and the economic philosophy, it is obvious that the obstacles to comprehension and utilization of these concepts, as we know them, are almost insurmountable.

Free enterprise, by definition, is a system of economic organization characterized by private ownership of the means of production and by the payment of profit to those who successfully undertake exceptional risks and to those who contribute inventions and innovations which prove to be utilitarian. In addition to private property and the profit motive, capitalistic systems also guarantee freedom of individual initiative, inheritance, and competition.

It is evident that differences in interpretation as to the definition of any of these basic components, and variations in the degree to which the component is stressed or deemphasized, will affect the evolution of the economic system. For example, the question of taxes on earnings can have an invigorating or a depressing effect upon individual and corporate endeavor. In the United States the imposition of progressive income taxes and relatively high inheritance taxes have been, together with other factors, instrumental in increasing the middle- and lower-income groups' share of the gross national product. As a consequence, the disposable income of these groups has risen significantly. This has led to tremendous extensive and intensive expansion of the American market. Without this mass market, serious limitations would have been imposed upon the development of mass production. This and similar cause-effect sequences, with their many ramifications, could be discussed at considerable length. However, at this point it seems adequate and logical to assume that both the structure and functions of our system of production are inextricably meshed with the philosophy of free enterprise. It should also be emphasized that the American version of free enterprise has many features which differentiate it from the economic system of the British Isles, and even more so from the several versions of socialism prevalent in Europe.

Even a cursory comparison of economic systems will reveal that certain business and industrial climates are conducive to growth whereas others tend to perpetuate the *status quo*. There are a number of attributes of the free-enterprise system which have been favorable to economic growth. Among these attributes is a remarkable flexibility, which facilitates the system's adaptation to war or peace, to prosperity and depression, to technological change, and to changes in social and political thought. This flexibility should not be assumed to function automatically. Rather, it is the product of numerous decisions made by entrepreneurs, unions, workers, government, and consumers, each

group presumably seeking its own advantage within the framework of the system.

Technological progress is another outstanding feature of free enterprise. The search for new products, better equipment, and improved manufacturing and marketing methods is stimulated in a system where productivity is the major yardstick in the apportionment of rewards. This aspect will be further analyzed in a subsequent chapter dealing with mechanization and its concomitants.

Another feature of our economic system is the remarkably high level of entrepreneurial energy, unmatched by any other society in the history of the world. This generation of dynamic drive depends not only upon the incentive of monetary reward, but probably even more upon a complex set of psychic ingredients such as the urges for self-expression, creativeness, dominance, and the like. One of the most serious imperfections of planned economies is the inability or the unwillingness of state planners to comprehend the nature of these entrepreneurial drives. The dependence of our economy upon the entrepreneur for top-level decision making will receive considerable attention throughout this text.

Another distinctive attribute of free enterprise is the efficiency with which it utilizes its productive resources. Critics of the system point to what they term the great waste of resources inherent in a system which permits an individual to exercise a high degree of free choice. The multiplicity of high-styled items, the high cost of advertising, the incidence of labor turnover, the losses incurred in labor disputes, the periodic occurrences of economic recessions, and a long list of similar supposed "inefficiencies" are set forth as an indictment of the system. Closer study should reveal that, while there might be a degree of waste in some of these practices, the sum of the losses is minimal when compared with systems where central planning supposedly eliminates such efficiencies. For example, there is a degree of therapy inherent in the right of workers to strike. Abridging this right would eliminate time lost due to strikes, but it would undoubtedly lower morale and thus cut productivity disproportionately. The strongest rebuttal to charges that our system does not utilize its resources effectively would come from a comparative analysis of the progress made during the past half century by the various economic systems.

While we are fully cognizant of the superiority of American free enterprise, we must not remain oblivious to what are, or could become, serious indictments. The excessive stress on materialism can provoke conflicts between pecuniary values and human welfare. The exploits of the nineteenth-century "robber barons," while highly successful

from a monetary point of view, might be severely criticized because of these rugged entrepreneurs' almost complete disregard for ethical, social, and human values. Yet despite the derogatory time-worn clichés about American materialism, it is obvious that a parallel progress has been made in the fields of education, medicine, social awareness, and elsewhere. It seems logical to infer that progress in the noneconomic spheres seems to be closely and positively correlated with economic advancement.

Among other major criticisms is the belief that economic inequality is inevitable in any system which rewards primarily on the basis of individual contribution. Karl Marx's indictment of European capitalism of the early and mid–nineteenth century is illustrative of complaints, real or imagined, against economic inequality.

In any controversy about the efficacy or inadequacy of an economic system, it seems logical to assume that praise or condemnation should be rendered strictly on the basis of performance. Judged in this manner, there can be no doubt that the socialistic doctrine of equality can scarcely compare with the free-enterprise stress on equity. Equity, to each according to his contribution, is obviously a more potent stimulant to high-level performance than is the socialistic "to each according to his needs," which is, in effect, an equality based on mediocrity.

COROLLARY 2. The Corporation

An allusion has already been made to the antiquity of economic joint ventures sanctioned by law. Although the Roman *societas publicanorum* probably should not be looked upon as the prototype of the modern corporation, there is a remarkable resemblance. The Roman joint ventures were initiated to underwrite projects requiring sums of capital so large that few of even the wealthiest citizens could individually handle the financing. The magnitude of the enterprise also usually meant that one person could hardly comprehend and control the technical and the supervisory aspects. Thus, a "public society" would provide better financing, better know-how, and better supervision and would undoubtedly be more influential in getting public and government support.

Present-day corporations are more directly descended from the great trading companies of the fifteenth to the eighteenth centuries. The first of these, the Merchant Adventurers, founded in the fifteenth century, was actually a form of business association rather than of business organization. The Merchant Adventurers were simply a band of merchants engaging in foreign trade and operating as a monopoly

under royal charter. They did not pool their capital, nor did they have centralized control. Such associations were known as regulated companies.

Out of these regulated companies there developed, during the seventeenth century, a variety of joint-stock company in which the capital was divided into negotiable shares. Unlimited liability and the refusal of governments to consider the joint-stock company as a legal person were the prime limitations.

Most of the early trading companies were financed by relatively small groups of wealthy men. However, about this time a revolutionary new concept of capital accumulation was popularized. It was discovered that thousands of ordinary citizens could, in driblets, supply equally large sums. The speculative boom of the early eighteenth century followed the participation of thousands of small investors in joint-stock ventures, many of which were simply schemes for fleecing the speculative-minded populace. The rash of "bubbles" and, in particular, the South Sea Bubble and John Law's equally scandalous Mississippi Bubble, threatened for a time to put an end to the participation of the ordinary citizen in joint-stock ventures. Legislation was even proposed to make illegal the division of joint-stock-company equity into small units. In all, it is estimated that about one and a half billion dollars was lost in England alone during the bubble frenzy.

Out of these misadventures there developed in the nineteenth century a type of business organization that possessed all the advantages of the joint-stock company together with two additional features: juristic personality and limited liability. This new financial organization was the modern corporation.

The classic definition of the corporation was set forth in 1819 by Chief Justice John Marshall in the often-referred-to Dartmouth College case. Marshall's definition states that "A corporation is an artificial being, invisible, intangible, and existing only in the contemplation of the law." The document further describes some of the more important characteristics of the corporation, which include immortality, individuality, perpetual succession, and the right to hold property.

Among the advantages which accompany incorporation are limited liability, divisibility and transferability of ownership, unlimited life, and representative management. On the other hand, there are a number of limitations such as rigid government regulation, a multiplicity of taxes, and the inability of stockholders to exercise effective control.

The superiority of the corporation as a medium of economic enterprise is obvious. Prior to the year 1800, there were only slightly more

than 300 business organizations in the United States with corporate charters. Presently there are more than 600,000. Although individual proprietorships and partnerships constitute about 85 per cent of the country's 4½ million business firms, they employ less than 10 per cent of the country's labor force and account for an equal percentage of its gross national product. In addition to employing the major portion of our labor force and accounting for most of our output, corporations provide the greatest single investment potential. Nearly 11 million stockholders have an equity currently valued at about $500 billion invested in corporation securities. The 1,016 big-board common stocks alone had a value, at the end of 1957, of more than $300 billion, based upon prevailing market prices. Among the largest concerns in number of stockholders are American Telephone and Telegraph with about 1,300,000 stockholders and General Motors Corporation with over 600,000 stockholders. Such widespread ownership is tangible evidence of the importance of this form of business organization.

The increasing importance of the corporation during the past four or five decades has highlighted the need for more and better managers and for improved managerial techniques. During the period when the owner-founder of a business concern actively dominated the company's affairs, there was little question about who was to decide what to do, and how, when, and where it was to be done. The passing of the era of entrepreneur-manager, the tremendous growth in the scale of operations, and the significant changes in the corporation's role in social and public affairs made imperative the need for a new type of industrial manager.

The new industrial leader cannot possibly know everything about every component part of the corporation. There has, consequently, been a marked need for staffs of experts upon whose advice the manager must rely. The development of the line-staff type of organization and of functional directors will be discussed in subsequent chapters. At this point it should suffice to stress that the corporation, together with the free-enterprise system, has probably been the greatest influence upon the evolution of the theory and practice of modern management. Without the corporation, and particularly the so-called big-business form of enterprise, there would have evolved a totally different concept of industrial management.

SIGNIFICANCE

Management can be termed the vivifying force which activates business-organization structures. A dynamic management engenders a mo-

mentum which manifests itself in an improved competitive status, growth in scale of operations, better products at lower prices, and a greater return to all participants. A sluggish management, on the other hand, is the best assurance that even a well-established organization will be run into bankruptcy. Prior to the Great Depression of the 1930s, the most significant factor of production was, unquestionably, money-capital. The dominance of finance in business was evident in the public attitude toward big business as an adjunct of Wall Street. During the past several decades references to financiers as the prime determinants of business endeavor have become less frequent. Instead we have become aware of the steadily increasing importance of management, its prerogatives and responsibilities. Where formerly economists referred to the feud between capital and labor, present-day writers speak of labor-management relations. There seems to be no doubt that management is today the strategic factor in production.

This designation of management as the strategic factor of production arises from the increasing complexity of business enterprise, which necessitates higher-caliber leadership. If the gross national product is viewed as the end result of the combined efforts of all factors of production, then a production equation might be set up to illustrate the role played by the respective factors. This production equation might read:

$$GNP = (F_M)^{n_1}[(F_{LB})^{n_2}(F_{LD})^{n_3}(F_C)^{n_4}]$$

In this equation *GNP* represents the gross national product. The letter *F* stands for the quantity of the pertinent factor. The subscripts designate the factor as management (*M*), labor (*LB*), land (*LD*), and capital (*C*). The exponents n_1, n_2, n_3, and n_4 represent the efficiency in application of the several factors. This production equation is set forth, not as an example for actual measurement of specific factor contribution, but rather as an illustration of how changes can occur in the relative importance of individual factors. Thus, as mechanization progresses, adjustments will be made in both the quantities of labor (F_{LB}) and capital (F_C) and in their relative effectiveness (n_2 and n_4). A decreased quantity of labor, but of an improved *quality* and with more effective utilization, can nevertheless increase considerably the contribution of LB^{n_2}, with consequent expansion of the product *GNP*. Similarly, changes in the quantity, quality, and efficiency in use of any of the factors will affect the value of the equation.

If this somewhat abstract presentation could be converted into actual figures, the growing importance of management would be clearly seen.

During the past two decades the quantity of management, measured in number of men, hours expended, or salaries paid, has increased at least fourfold. At the turn of the century about 1 out of every 1,100 employees was either a manager, scientist, engineer, or skilled technician. Today the comparable ratio is estimated to be approximately 1 out of every 60 employees. The quality of managerial ability and the effectiveness in its utilization, although difficult to measure, can reasonably be assumed to have improved markedly. Thus the increased value of both F_M and the exponent n_1 would result in a greater gross national product even if the other factors remained constant. However, simultaneously raising the values of the other terms yields a geometric pattern of progression. This geometric progression is basic to the concept of productivity, that is, the rate of increase of output measured per unit of a specific input such as man-hours, machine-hours, or dollars invested. Because of its fundamental importance the concept of productivity will be analyzed in detail in subsequent chapters.

The illustration of the production equation might be subject to technical debate. It does, however, show the interdependence of all the factors of production. In setting the management factor $F_M^{n_1}$ outside the brackets, attention is focused upon the primacy of the management factor in modern enterprise. This interdependence, together with the primacy of the management factor, is a basic premise in this text.

ILLUSTRATION 1. Socrates' Discourse with Nicomachides

Seeing Nicomachides, one day, coming from the assembly for the election of magistrates, Socrates asked him, "Who have been chosen generals, Nicomachides?" "Are not the Athenians the same as ever, Socrates?" he replied; "for they have not chosen me, who am worn out with serving from the time I was first elected, both as captain and centurion, and with having received so many wounds from the enemy (he then drew aside his robe, and showed the scars of the wounds), but have elected Antisthenes, who has never served in the heavy-armed infantry, nor done anything remarkable in the cavalry, and who indeed knows nothing, but how to get money."

"Is it not good, however, to know this," said Socrates, "since he will then be able to get necessaries for the troops?" "But merchants," replied Nicomachides, "are able to collect money; and yet would not, on that account, be capable of leading an army."

"Antisthenes, however," continued Socrates, "is given to emulation, a quality necessary in a general. Do you not know that whenever he has been chorus-manager he has gained the superiority in all his choruses?" "But, by Jupiter," rejoined Nicomachides, "there is nothing similar in managing a chorus and an army."

"Yet Antisthenes," said Socrates, "though neither skilled in music nor in teaching a chorus, was able to find out the best masters in these departments."

"In the army, accordingly," exclaimed Nicomachides, "he will find others to range his troops for him, and others to fight for him!"

"Well, then," rejoined Socrates, "if he find out and select the best men in military affairs, as he has done in the conduct of his choruses, he will probably attain superiority in this respect also."

"Do you say, then, Socrates," said he, "that it is in the power of the same man to manage a chorus well, and to manage an army well?" "I say," said Socrates, "that over whatever a man may preside, he will, if he knows what he needs, and is able to provide it, be a good president, whether he have the direction of a chorus, a family, a city, or an army."

"By Jupiter, Socrates," cried Nicomachides, "I should never have expected to hear from you that good managers of a family would also be good generals." "Come, then," proceeded Socrates, "let us consider what are the duties of each of them, that we may understand whether they are the same, or are in any respect different." "By all means," said he.

"Is it not, then, the duty of both," asked Socrates, "to render those under their command obedient and submissive to them?" "Unquestionably." "Is it not also the duty of both to appoint fitting persons to fulfill the various duties?" "That is also unquestionable." "To punish the bad, and to honour the good, too, belongs, I think, to each of them." "Undoubtedly."

"And is it not honourable in both to render those under them well-disposed towards them?" "That also is certain." "And do you think it for the interest of both to gain for themselves allies and auxiliaries or not?"

"Certainly; but what, I ask, will skill managing a household avail, if it be necessary to fight?" "It will doubtless, in that case, be of the greatest avail," said Socrates; "for a good manager of a house, knowing that nothing is so advantageous or profitable as to get the better of your enemies when you contend with them, nothing so unprofitable and prejudicial as to be defeated, will zealously seek and provide everything that may conduce to victory, will carefully watch and guard against whatever tends to defeat, will vigourously engage if he sees that his force is likely to conquer, and, what is not the least important point, will cautiously avoid engaging if he finds himself insufficiently prepared."

"Do not, therefore, Nicomachides," he added, "despise men skillful in managing a household; for the conduct of private affairs differs from that of public concerns only in magnitude; in other respects they are similar; but what is most to be observed, is, that neither of them are managed without men; and that private matters are not managed by one species of men, and public matters by another; for those who conduct public business make use of men not at all differing in nature from those whom the managers of private affairs employ; and those who know how to employ them, conduct either private or public affairs judiciously, while those who do not know, will err in the management of both." [2]

[2] Plato and Xenophon, *Socratic Discourses,* book III, chap. 4, translated bv J. S. Watson, Everyman's Library, E. P. Dutton & Co., Inc., New York, 1910.

QUESTIONS

1. Comment on the Athenian method of selecting generals.
2. What qualities in addition to those mentioned by Socrates should a manager of a modern organization have?
3. What attributes do Socrates and Nicomachides agree are essential to effective management?
4. Is excellence in a nonrelated field an adequate criterion for selection of a top executive?
5. What other managerial principles and practices are inferred?

ILLUSTRATION 2. Veblen's Views

In hedonistic theory the substantial end of economic life is individual gain; and for this purpose production and acquisition may be taken as fairly coincident, if not identical. Moreover, society, in the utilitarian philosophy, is the algebraic sum of the individuals; and the interest of the society is the sum of the interests of the individuals. It follows by easy consequence, whether strictly true or not, that the sum of individual gains is the gain of the society, and that, in serving his own interest in the way of acquisition, the individual serves the collective interest of the community. Productivity or serviceability is, therefore, to be presumed of any occupation or enterprise that looks to a pecuniary gain; and so, by a roundabout path, we get back to the ancient conclusion of Adam Smith, that the remuneration of classes or persons engaged in industry coincides with their productive contribution to the output of services and consumable goods.[3]

QUESTIONS

1. In the light of Veblen's teaching, what is the function of the manager?
2. How might "the algebraic sum of the interests of the individuals" be maximized?
3. Does this utilitarian philosophy exclude all nonmonetary values?

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CHAPTER 2

Scientific Management

DEFINITION AND DESCRIPTION

The terms *science* and *management* have been defined and explained in the previous chapter. It seems evident that a definition of scientific management should include the essential features of both the terms. This composite definition might state that scientific management consists in the systematic collection and arrangement of pertinent data from which general laws, principles, and precepts are derived for maximizing the creation of utility through improved decision making and control over the combination of productive factors. This rather cumbersome definition simply means that all important decisions as to what is to be done in industry and what means are to be used should be based upon rules drawn from observation, experimentation, and thought. The authority of data would then supersede that of custom and chance.

Scientific management's reliance upon empiricism serves to distinguish it from earlier managerial methods. The thought-action sequence, typical of scientific management, can be summarized as follows: There is initially a period of confusion arising out of uncertainty. Individuals with aspirations and ability become concerned about how this confusion may be resolved. This concern leads to phase 2, the scientific process proper. Applying the scientific method, the concerned individuals should collect all pertinent facts. The mass of information serves no purpose unless it is arranged according to sub-

ject matter, etc. Thus classification of all data is a requisite concomitant. Pigeonholing the facts makes logical inference possible. This step, by which inferences are drawn, can be termed correlation since relationships can be discerned through any of a variety of judgment processes. Correlation leads to the derivation of conclusions, which, after being verified, are applicable to the solution of problems and the pursuit of selected courses of action. This application of specific conclusions, arrived at by the scientific process, differentiates scientific management from systematic management, and particularly from arbitrary and haphazard forms of industrial control. Presumably the effectiveness of these techniques should be checked or corroborated periodically. As circumstances warrant, revisions must be made in the scientific techniques of control, in the courses of action being followed, and even in the basic objectives of the enterprise.

This sequence from confusion to control has a motivating factor, namely, the satisfaction of wants or desires. Such a want-satisfaction yields contentment, even if for only relatively short spans of time. However, in a dynamic situation the never-ending pressures of new wants bring about a disequilibrium characterized by new problems and a return to confusion. Thus a new cycle is initiated and the process is repeated. The basic steps in the application of the scientific methodology are listed in a mnemonic alliteration:

Initiating factors	**1. Confusion**
	2. Concern
Scientific factors	**1. Collection of facts**
	2. Classification of data
	3. Correlation of factors
	4. Conclusions inferred
	5. Corroboration of conclusions
Objectives	**1. Control of a situation**
	2. Contentment

Among the most significant advancements which helped in the evolution of scientific management were (1) the discovery of the laws of probability, and (2) Frederick Winslow Taylor's adaptation of scientific methodology to industrial management. Both these topics will be discussed in subsequent sections: Taylor's contribution in the next heading, and the theory of probability in the chapters dealing with decision making and quality control. At this point only a cursory reference will be made to the term probability, specifically for purposes of definition.

The theory of probability is concerned with determining the likelihood that, under certain circumstances, a given chance event will occur. For example, clouds are generally associated with rain, yet common sense tells us that not every cloudy day will bring rain. What, then, are the chances that if today is cloudy, rain will follow? Before a rational answer can be given, it is obvious that additional information is needed. The ability to predict accurately depends upon the judicious segregation and study of all pertinent factors. These factors are the variables, some of which are quite important in the making of this specific prediction and others of which are rather immaterial. In assaying the probability of rain, variables such as the direction and velocity of the wind, the type of clouds, barometric pressure, temperature, humidity, etc., are relevant. Other variables, such as the time of day and the day of the week, are obviously of little significance. The process of determining probabilities follows substantially the same sequence described as the scientific process and summarized in the preceding nine-*C* mnemonic. The fundamental differentiating feature is the stress on quantification, that is, the translation into numerical terms of the likelihood of occurrence of any specific event. This and several other aspects of probability theory and application will be described in subsequent chapters.

Taylor's adaptation of scientific methodology is so well known that only a few of the highlights will be mentioned in this text. Although Frederick Winslow Taylor is generally considered to be the Father of Scientific Management, he was emphatic in disclaiming that he was the discoverer of the basic scientific-management principles.[1]

> It will doubtless be claimed that in all that has been said no new fact has been brought to light that was not known to some one in the past. Very likely this is true. Scientific management does not necessarily involve any great invention, nor the discovery of new or startling facts. It does, however, involve a certain *combination* of elements which have not existed in the past, namely, old knowledge so collected, analyzed, grouped and classified into laws and rules that it constitutes a science, accompanied by a complete change in the mental attitude of the working men as well as those on the side of management toward each other and toward their respective duties and responsibilities. Also a new division of the duties between the two sides and intimate, friendly cooperation to an extent that is impossible under the philosophy of the old management.

In a sense, Taylor was a synthesizer and popularizer of ideas which had previously been demonstrated. Thus he performed for scientific

[1] Frederick Winslow Taylor, *The Principles of Scientific Management*, Harper & Brothers, New York, 1911, pp. 139–140.

management what Adam Smith did for classical economics and Sir William Blackstone did for law. It would be preposterous to postulate that prior to Taylor all manufacturing was done on a hit-and-miss basis. Record keeping, cost calculation, division of labor, delegation of authority, the line-and-staff principle, profit maximization, and similar concepts are as old as industry itself. However, with the rapid growth of industrial enterprise the need became manifest for a more detailed and more systematized approach, first to the techniques of production, and then to the concepts of management. Taylor was the first to recognize and call public attention to the fact that industrial management had already passed through its pioneering phase and was ready for institutionalization.

In substance, Taylor proposed that scientific management was the culmination of an evolutionary process. The first stage in the development was nonsystematized enterprise. This grew up with a specific plant. As a result, such managements were usually inbred and bound by tradition. They placed an inordinate emphasis on immediate profit and had little inclination to make changes. New methods generally came fortuitously and were spread by imitation.

In the second phase—systematic management—there was a keen realization that past performance should be a guide to future action, and thus record keeping assumed a new importance. Need for written directions, standard procedures, cost estimation, and improved communication was necessitated by the tremendous increase in the scale of operation. Although there was some experimentation, it was not the precise laboratory method of observation and measurement of large samples.

The next stage in development was scientific management, characterized as the most important advance in industry since the introduction of the factory system and power machinery. Taylor enumerated four fundamental principles that differentiate scientific management from other forms of industrial control:

1. The development of a science should replace the old rule-of-thumb methods. In his study of metal-cutting tools, Taylor and his associates recorded nearly 50,000 individual experiments, in the course of which 800,000 pounds of metal were cut into chips and the total cost of experimentation in current dollars ran in excess of $1 million. Out of such masses of data, classified and studied, came new standards of productivity and methods for attaining these standards. Yet in these experiments there is no assumption of finality, for there is always the probability that new methods and new laws might be discovered.

2. There should be scientific selection and then progressive teaching

and development of the workmen. The two illustrations at the end of this chapter adequately show the importance of this principle.

3. The scientifically selected workmen and the scientific method of performing the operation must be brought together.

4. There must be an intimate cooperation between management and the work force, with a mutual recognition of the benefits of mutual helpfulness.

The most important mechanisms needed to put these principles into operation include:

1. Reduction of industrial processes into basic units
2. Determination of the most efficient motions
3. Time study for the setting of standard times
4. Functional foremanship, with each foreman an expert in a single activity
5. Careful planning, scheduling, and routing
6. Specifications for each operation
7. Differential wage-incentive systems
8. Proper training for all operatives

DEVELOPMENT

One of the first recorded instances of the scientific method being applied to the general area of management was in the field of government administration. Aristotle and his students collected 158 constitutions of Hellenic and barbarian states. Using these data, Aristotle made a comparative study from which he deduced certain principles of government. This scientific, or at least systematic, endeavor is in sharp contrast to the approach used by another outstanding Greek philosopher. "Plato sat in the comfortable home of his friend Polemarchus in the Piraeus and constructed his city from the materials contained in his mind and in the minds of his companions, appealing to reason to support his theories." [2] The ideal city-state, as described in *The Republic,* is the product of this reliance upon what Plato and his associates assumed to be reason. The unrealistic, and in some cases even unnatural, existence of the citizens in this hypothetical city is the basic reason why this and similar utopias have never been successfully established. Even Plato in his lifetime recognized some of the flaws. In *The Republic* he postulates that his guardians and rulers should have no private property. "Should they ever acquire homes or lands or moneys of their own they shall become house keepers and husbandmen instead of guardians, enemies and tyrants instead of allies of the other citizens.

[2] James P. Lichtenberger, *Development of Social Theory,* Appleton-Century-Crofts, Inc., New York, 1938, p. 52.

Hating and being hated, plotting and being plotted against, they shall pass their whole life in much greater terror of internal than of external enemies." [3] However, in *The Laws,* published posthumously, Plato reports his disillusionment. His only real experiment in training a philosopher-king had collapsed miserably when Dionysius II, Tyrant of Syracuse, proved to have human failings rather than the necessary angelic attributes. Thus in *The Laws,* Plato realistically states that the land and houses should be distributed and the land should not be tilled in common "since a community of goods is beyond their proposed origin and nature and education." [4] In *The Laws* Plato concedes the individualization of production. This illustration points out the need for empiric techniques and the weakness of untested hypotheses. There can be no doubt that Aristotle's comparative analysis of the 158 city-state constitutions was a much more realistic study than was Plato's utopia. Similarly, in any area of activity, plans and objectives based upon hunch, rule of thumb, intuition, or pure reason are likely to yield ineffective results.

Despite the recognition by a few of the early enlightened thinkers that realism rather than speculation might be preferable in designing the framework for organized action, very little progress was made in this direction for hundreds of years. The decline of Rome and the retrogression during the Dark Ages put an end to what might ultimately have developed into a full-fledged scientific methodology. During the early portion of the Middle Ages monasticism and the Scholastics kept the spark of learning flickering. However, the dogmatic assumptions of the Scholastics, who postulated that there was a specific body of subject matter which was absolute and infallible, served to restrict the search for truth to relatively narrow limits.

It was not until the period of the Crusades, when Western Europeans came into closer contact with Eastern ideas, that the reawakening of learning had a strong impetus. The Eastern nations had not only kept alive the ancient Greek heritage but had also developed a high degree of proficiency in areas such as astronomy, art, mathematics, physics, and chemistry. As a direct result of the Crusaders' contacts with Eastern learning, a few of the more enlightened Western minds began to dabble in the rediscovered fields.

During the twelfth to fifteenth centuries, a series of universities were founded in the major cities of Western Europe. These medieval universities were instrumental in the awakening of intellect and the

[3] *The Dialogues of Plato,* translated by B. Jowett, 3d ed., vol. III, *The Republic,* Oxford University Press, London, 1892.

[4] *Ibid., The Laws.*

gradual evolution of the research method. In particular, it was in the academic discussions at these medieval universities that the absolute and supposedly unquestionable dogma of the Scholastics came under scathing scrutiny. This spirit of doubt eventually led to the serious questioning of the source of authority. The dispute about whether the source of authority was spiritual or temporal finally led to the religious, political, social, and academic upheavals which have come to be known as the Renaissance.

This very brief survey of the historical is intended only to illustrate the slow process of transition from the unquestioning acceptance of dogma to the never-ending probing of the scientific method. There have been numerous contributors to this transition—the earliest of whom have been overlooked in the hazy history of eras which placed a premium on the whims of monarchs and little value on the efforts of the scientific-minded. A detailed study of the very gradual elevation of the scientific method to a position of dignity would be both time-consuming and somewhat beyond the scope of this text. Consequently, no further attention will be given at this time to the status of the scientific method during the twenty-two centuries between Aristotle's use of the comparative method in his study of ancient Greek governments and the accepted use of substantially the same technique in modern industry. Of immediate concern is the emergence, late in the nineteenth century, of what is presently known as scientific management.

History has recorded very little about the early pioneering ventures into the area we have come to designate as scientific management. For example, Charles Babbage's *The Economy of Manufacturers,* published in 1832, is generally assumed to be the first reference to the importance of determining task times as a prerequisite for efficient performance. Yet Babbage had considerable knowledge of the over-all time standards then used in quite a few industries. It is said that Babbage was indebted for his ideas on this subject to a Monsieur Coulomb and to a Monsieur Perronet, the latter a pin manufacturer who made considerable use of over-all time studies of the major operations in pin making.

James Watt, Jr., and an associate, Matthew Boulton, both sons of pioneers in the development of the steam engine, were said to have applied a variety of modern management methods from 1795 onward in their Soho Foundry. These techniques included standardization of product components, work study, production planning, operating standards, and incentive-wage payments.

As has already been intimated, the earliest scientific-management ventures might be termed fragmentary and disjointed. There was no

such thing as an integrated body of precepts, nor even an identifiable movement. Reference has been made to Frederick Winslow Taylor's role of synthesizer-innovator-popularizer of the revolutionary scientific-management concept. It seems appropriate at this point to mention one or two sidelights on Taylor's championing of the new way of industrial life.

Frederick Winslow Taylor's first contact with industry occurred at the age of sixteen, when, because of serious eye trouble, he had to give up a proposed law career after he had been admitted to Harvard. He went to work as a day laborer in a Philadelphia machine shop where, by 1884, he had been promoted in rapid succession until he became chief engineer. In his capacity as a plant official, Taylor recognized that despite the superior and often even the arrogant attitude displayed by management toward the rank-and-file workers, it was actually these workers who ran the plant. They restricted output quotas and limited the effectiveness of work methods. Until management could determine the best way and the best time in which a specific operation could be performed, effective control in industry was seriously limited.

Taylor's indictment of featherbedding by workers and gross incompetence and deplorable apathy in management served to antagonize both these powerful groups. He had virtually no support from either party. John Dos Passos, in *The Big Money,* rather forcefully describes "Speedy" Taylor's position: "Production went to his head and thrilled his sleepless nerves like liquor or women on a Saturday night. He never loafed and he'd be damned if anybody else would. Production was an itch under his skin. He lost his friends in and out of the shop and Taylor himself wrote: 'It's a horrid life for any man to live, not being able to look any workman in the face without seeing hostility and feeling that every man around you is your virtual enemy.' "[5] Despite the almost universal opposition, Taylor's dedication did not diminish.

Over a period of twenty-six years, Taylor and his associates accumulated a mass of data out of which Taylor derived his principles of scientific management. Two of his best-known experiments are described at the end of this chapter.

Although Frederick Taylor is the acknowledged Father of Scientific Management, the movement was facilitated by a number of equally dedicated pioneers. A historical record of the lives and works of the 20 most important contributors to this field was prepared in 1956 by the International Committee of Scientific Management in its publica-

[5] John Dos Passos, *The Big Money in U.S.A.*, Houghton Mifflin Company, Boston, 1946, p. 23.

tion *The Golden Book of Management*. Outstanding among these early proponents of the scientific method in management are the following.

Henry Robinson Towne. As president of the American Society of Mechanical Engineers, he was able to give Taylor strong support at a time when Taylor's views were generally regarded as impractical. His paper "The Engineer as Economist," written in 1886, was one of the earliest written statements of the changing concept of management. His gain-sharing plan, put into operation in 1889 in his own plant, is the earliest plan for profit sharing on the basis of the relative efficiency of individual departments.

Captain Henry Metcalfe. His book *The Cost of Manufacture and the Administration of Workshops, Public and Private,* published in 1885, was the first example of a complete system of shop returns based on the unit principle.

Carl G. L. Barth. The Barth slide rule made possible the mathematical analysis of the data accumulated in Taylor's experiments. In addition to being the mathematician on Taylor's team, Barth was also the "system man" who put into practice many of the conclusions deduced from these experiments.

Henry L. Gantt. Gantt stressed the importance of the human element in management. He has been called the first exponent of democracy in industry. Whereas Taylor tended to antagonize both management and labor groups, Gantt's good influence helped sell the scientific-management philosophy to both groups. He is well known for his task-and-bonus wage-incentive plan and for his work in the graphic presentation of management concepts. The Gantt chart has come to be synonymous with continuous preplanning and production control.

Henri Fayol. The isolation and analysis of administration as a separate function was Fayol's major contribution. He stressed that the theory of administration was equally applicable to all forms of organized human cooperation. In contrast with Taylor, who deduced scientific-management principles from workshop experimentation, Fayol analyzed primarily those functions concerned with top-management policy formulation.

James Mapes Dodge. Dodge was the first American industrialist to introduce Taylor's ideas as a unified system into an industrial enterprise. As president of the Link Belt Company, he converted the Philadelphia plant to the Taylor system and proved the practicability of scientific management.

Harrington Emerson. A prolific writer, Emerson was concerned chiefly with the influence of psychological factors upon efficiency. He

expounded the concepts of standard times, standard costs, and waste prevention. The Emerson wage-payment plan introduced the idea of a high task but with premiums, beginning at about two-thirds of task and increasing in geometric ratio. He was also the first to emphasize the similarity between business and military organization.

Frank Bunker Gilbreth. Stressing the concept of "the one best way," Gilbreth expanded the field of motion study. His adaptation of the movie camera for work-study purposes resulted in the development of micromotion analysis. Gilbreth focused attention upon management as a social science, with particular attention to the human being as the focal point in all industrial endeavor. In his three-position plan of promotion, developed jointly with his wife, Dr. Lillian Moller Gilbreth, he anticipated the now prevalent management-development programs.

Space limitations prevent a more detailed commentary on the contributions of these founders of scientific management. Of necessity many names, such as James Rowan, Frederick Halsey, Joseph Slater Lewis, Karol Adamiecki, Mary Parker Follett, and others, can only be mentioned as being important in the development of modern management. The interested student can refer to the bibliography for more detailed sources of information concerning the contributions of these and other early proponents of science in management.

COROLLARY 1. A Philosophy of Management

When men attempt to explain their actions in terms of objectives and the means necessary to attain these objectives, they invariably begin to philosophize. Eventually, when a large group accepts one specific pattern of action through which it hopes to attain a given goal, a new philosophy is evolved. Thus it might be said that a philosophy is a system of thought which explains certain phenomena and prescribes a set of principles for resolving problems related to the attainment of a specific goal. In brief, a philosophy is a way of life. In every instance a philosophy has (1) an established goal, (2) a set of values related to the attainment of that goal, and (3) a firm conviction on the part of the "believers" that these values and the ultimate goal are worth striving for.

The new management philosophy has as its established goal the attainment of a better and happier way of life for more and more people. This noble aspiration is basic to a great number of philosophies. The differentiating feature is found in the means employed in the attainment of that goal and in the specific set of values employed. Some older ways of life postulated that the attainment of true happi-

ness could be achieved by (1) shunning material things, (2) passive resignation to the *status quo,* (3) converting the "heathen" by the sword, and (4) living for the day, and by a host of contradictory sets of values. The stoic and the epicure might be said to advocate antithetical codes of action, yet both partisans are seeking the same ultimate goal. Similarly, the free-enterprise and the socialist philosophies propose the use of radically different means by which they hope to attain rather similar ends. With value norms as with individual tastes, attempts at conversion frequently lead to violence. In the long run, the staying power of any philosophy depends upon the intensity of conviction of its adherents.

Included in the set of values which differentiates the modern management philosophy is a belief that:

1. Material progress can be conducive not only to physical but also to mental and spiritual well-being.

2. Cooperation among all the factors (of production) leads to an improved morale and the maximum efficiency.

3. Efficiency is maximized when management makes available to its personnel opportunities commensurate with abilities.

4. An individual's contribution should be the measure of his reward.

5. Freedom of individual choice is paramount and should not be subordinate to regimentation by central planning agencies.

6. New methods and new implements are the means by which progress, social as well as economic, can be accelerated.

These six factors, together with many others too numerous to list, differentiate the modern management philosophy from all other ways of life. The power of this new philosophy is evident in the enthusiasm of its adherents and in the high degree of attainment of objectives.

COROLLARY 2. A Management Profession

In the broad sense, a profession is any area of human activity with established standards and rules of conduct concerned with the performance of services. Generally, there are several differentiating features which elevate a trade or occupation to the loftier eminence of a profession. Among these features are:

1. A clearly defined code of ethics
2. Self-policing and voluntary restraints
3. Rigid entrance requirements
4. Continuous development of its members through group association in conferences, seminars, etc.
5. Membership in specific professional societies

6. Emphasis on the priority of service to the client and society over and above the monetary rewards
7. A bond of trust between the professional and his client
8. Recognition from without (includes social status for the professional)

An analysis of modern managers, in respect to the enumerated traits of the professional, clearly indicates a modification in the business-leader type during the past half century. The transition from the stereotype of the robber baron to the modern manager type has been initiated and accelerated by a great variety of factors, among which are:

1. Separation of ownership and control in our larger corporations. This topic will be elaborated upon in a subsequent chapter.
2. Enunciation by the Federal government of its responsibilities to protect its citizens from exploitation. The Sherman Act and similar legislation are evidence of this attitude.
3. Growth of the trade-union movement since the founding of the American Federation of Labor in 1886.
4. Desire of industrial leaders for social status.
5. Impetus of the scientific-management philosophy, which stresses the need for technically trained professional managers.

It would be rather difficult to date the inception of management as a profession. Former President Lowell of Harvard University once described business administration as "one of the oldest of the arts and the youngest of the professions." Individual spokesmen probably began to theorize, at least a hundred years ago, about the need for managerial standards, a code of ethics, etc. General Robert E. Lee is said to have been one of the first to recognize the need for specialized schools of business. In 1869 he urged Washington and Lee University to develop a curriculum for teaching business. His suggestion did not materialize at that school for another thirty-seven years. However, in 1881, the University of Pennsylvania established the Wharton School of Finance and Commerce. This was the first institution of learning in which students would be instructed for business in a fashion similar to the way in which aspirants to the older professions were trained. The founders of the Wharton School were resolved to elevate the field of business to that of a profession. The relatively slow growth of this idea is manifest in the fact that no other schools of business were started prior to 1898 when the Universities of Chicago and California followed suit.

Currently there are 220 colleges and universities offering degrees in business. These institutions have a combined enrollment of about one-

quarter million students. The emphasis on raising standards has even resulted in the establishment of regional accrediting associations, working in conjunction with the American Association of Collegiate Schools of Business, in which approximately half the country's business schools have been accepted as members.

This professionalization of business as manifest in the sphere of education is paralleled by the growth of professional societies. The American Society of Mechanical Engineers, although only indirectly connected with business, was the first organization sponsoring group activity in this field. In 1886 Henry R. Towne, later one of the founders of Yale and Towne Manufacturing Company, presented his paper "The Engineer as Economist" to the annual meeting of the ASME. It is generally accepted as the first professional paper in the business field. For the next three decades the meetings of the ASME afforded practically the only medium for the presentation of professional papers in the field of industrial management. However, even the ASME did not officially recognize the subject of management engineering until 1907. For almost another decade a very large and influential portion of the ASME membership vehemently denied that there could be any science of management. Nevertheless, the *Transactions* of these meetings and the *Engineering Magazine* were the only publications carrying items of interest to the professional manager. Early in the first decade of the present century, the magazine *System* appeared. This was the first publication specifically dedicated to the discussion of industrial management concepts and practices. The number of publications has now grown to such a proportion that it would be impractical to attempt to list them. Among some of the better known of these periodicals are *Fortune, Business Week, Harvard Business Review, Factory Management and Maintenance, Mill and Factory, Personnel,* and *Production.* This is only a partial listing of periodicals entirely dedicated to the coverage of industrial management items. There are hundreds of additional publications in closely related fields, such as finance, accounting, marketing, and transportation. News periodicals, such as *Time, Wall Street Journal, Barron's, The New York Times,* and many others, also give excellent news coverage of developments in the management sphere.

Professional societies, once represented solely by a small group within the ASME, have likewise multiplied. In addition to the hundreds of employers' associations and trade unions, there are numerous technical and learned groups further striving to professionalize their areas. Outstanding in this category are the American Management Association, the Society for the Advancement of Management, the Academy of Management, etc. Since 1924 there has even been an In-

ternational Committee of Scientific Management which conducts triennial international congresses in which the top-management authorities of the world participate.

The hundreds of conferences, seminars, management courses, and similar group activities testify to the spirit of professionalization prevalent in this field. The increase in the number of development and techniques courses at the executive, supervisory, and foreman levels further substantiates this contention. These courses have attained a measure of respectability, being included in the offerings of most of our best universities. Most progressive corporations have, in addition, special intensive management-training programs, frequently extending over a period of from two to four years.

The growth of the management-consultant practice is another indication of the coming of age of the management profession. Twenty years ago there were a few hundred management consultants. By 1954 the number, according to a survey by the Association of Consulting Management Engineers, was in excess of 1,900. It is highly probable that the spreading of the management-consultant concept will in the near future do much to hasten professionalization to an even greater degree. The emphasis on client-consultant relations, on a management code of ethics, and on self-policing will undoubtedly prove to be beneficial in the long run.

As a final point, the emphasis on professional certification is gaining momentum. As early as 1896 New York State passed legislation relative to certification in public accounting. The New York legislation set fairly rigid standards for accountants who, after serving a specified period of apprenticeship and passing certain examinations, could use the label of certified public accountant (CPA). More recently two comparable designations with equally rigid qualifications have been established in the fields of insurance—chartered life underwriter (CLU) and chartered property casualty underwriter (CPCU). In the area of secretarial work, an attempt at professionalization has been made with the establishment of norms for the title of certified professional secretary (CPS). If this trend should continue, it is very likely that licensing of practitioners will be the rule in areas such as quality control, personnel management, training, and the like.

SIGNIFICANCE

Frank B. Copley, Frederick Taylor's best-known biographer, quotes Taylor's indignant reply[6] to severe criticism from a House of Repre-

[6] Testimony before the Special Committee of the U.S. House of Representatives, 1912, F. W. Taylor, *The Principles of Scientific Management*, Harper & Brothers, New York, 1917.

sentatives Special Committee investigating the potential of scientific management:

> Scientific Management is not an efficiency device, nor is it any bunch or group of efficiency devices; it is not a new system of figuring costs; it is not holding a stop-watch on a man, and writing things down about him; it is not time study; it is not motion study; it is not the printing and ruling and unloading of a ton or two of blanks by a set of men saying "Here's your system, go to it;" it is not divided foremanship, or functional foremanship; it is not any of the devices which the average man calls to mind when Scientific Management is spoken of. Now, in its essence, Scientific Management involves a complete mental revolution on the part of the working man engaged in any industry, and it involves an equally complete revolution on the part of those on the management's side—the foreman, the superintendent, the owner, the board of directors, and without this complete mental revolution on both sides Scientific Management does not exist.

It is this "mental revolution" which created a totally different frame of mind among both workers and management and stimulated economic and social progress. It is obvious that progress is neither self-generating nor self-perpetuating. Consequently, it is the province of individuals, some of whom are dreamers and others of whom are experts at translating dreams into reality, to supply the impetus which propels society from inertia to progress.

The success of any economic or social system is measured by the satisfaction rendered to its members. Using this criterion, it is evident that modern management is quite superior to any other system the world has previously known. However, it must be remembered that there is no guarantee that this new and better way will continue indefinitely. Archaeological remains testify to the grandeur of now barely remembered civilizations. Staying power, the ability to adapt to changing environments, and related traits are requisite. The Seven Wonders[7] of the ancient world are still regarded as remarkable engineering-production-artistic feats. These monuments also testify to the fate which befalls any nation which can no longer adjust to changing circumstance.

To most Americans the Seven Wonders of the ancient world have relatively little inspirational value. These splendors of the past have been relegated to the venerable status of museum curios. Our industrial system has, figuratively speaking, supplanted the Seven Wonders

[7] About 200 B.C. Antipater of Sidon listed the seven greatest sights of the world as (1) the Pyramids of Egypt, (2) the Hanging Gardens of Babylon, (3) Phidias's statue of Zeus at Olympia, (4) the Temple of Artemus at Ephesus, (5) the Tomb of Mausolus, (6) the Colossus of Rhodes, (7) the Pharos Lighthouse at Alexandria.

of old with a modern seven thousand wonders. Even if we restricted our comparison to the number seven, the superiority of the present era is obvious. Late in 1955 the American Society of Civil Engineers polled its 38,000 members as to the seven greatest construction projects of the twentieth century in the United States. The engineers' criteria included, in addition to size, the usefulness, beauty, and pioneering design and construction of the project. The engineers' choices are (1) the Grand Coulee Dam, (2) the Hoover Dam, (3) the San Francisco–Oakland Bridge, (4) the Panama Canal, (5) the Empire State Building, (6) the Chicago Sewage System, and (7) the Colorado Aqueduct.

It would be quite misleading if only the spectacular engineering accomplishments were viewed as modern wonders. The truly significant accomplishments might be said to be:

1. The steadily increasing population (despite Malthus's dire predictions)
2. The increasing life expectancy due to better food and better medical care
3. The rise in real income with its attendant material benefits
4. The increased time for leisure and for appreciation of the finer things of life
5. The tremendous strides in the field of education
6. The relative stability of our government
7. The never-ending search for new and better ideas

In summary, there seems to be no doubt that the American economy has outstripped the rest of the world. Of the many reasons for this excellence, the ability of American managers to combine all the factors of production most effectively seems to be paramount. This managerial superiority is the product of an understanding and an application of scientific-management principles.

ILLUSTRATION 1. Taylor's Pig-iron Experiment

In the production of pig iron it is economic to run the blast furnaces continuously, halting the operations only for major repairs. One of the chief factors for this characteristic is the relatively high cost entailed in starting and in stopping the operation. As a consequence, steel producers, during a slack period, frequently store the surplus pig iron in anticipation of an improvement in demand.

Immediately prior to the Spanish-American War, depressed prices in the iron and steel market resulted in the Bethlehem Steel Company's storing of about 80,000 tons of pig iron in an open field adjacent to the producing facilities. With the outbreak of hostilities, the demand for pig iron improved and this stock-piled pig iron was sold.

Shipment to the buyer necessitated running a railroad switch alongside the piles of stock-piled pig iron, placing an inclined plank from the car to the ground, and moving the pigs, each weighing about 92 pounds, onto the railroad cars. The company had a gang of 75 men engaged in transporting the finished product of its five blast furnaces. The gang was about average for the industry in its level of performance. In this specific operation, the loading of the pig iron on the railroad cars, this gang averaged 12½ long tons per man-day, for which the average pay was $1.15.

Frederick Taylor, in his attempt to demonstrate the superiority of task work over day work, studied the movements of the 75 men, from whom he selected 4 men who appeared to be physically capable and emotionally suitable for his experiment. After carefully analyzing the backgrounds and traits of the 4 men, he finally selected a relatively small man who, for anonymity purposes, he designated as Schmidt. In addition to being a conscientious worker, Schmidt was frugal, trotting more than a mile to work and then home after work, presumably to save carfare. One of his associates characterized Schmidt, saying, "A penny looks about the size of a cartwheel to him."

After Schmidt agreed to follow Taylor's instructions, for which Schmidt's pay would be elevated to $1.85 per day, Taylor proceeded to show how the "first-class man" should perform the operation. This work was rather basic, requiring no skill or special-purpose tools. The motions consisted in simply bending, picking up the pig, walking up the incline, dropping the pig upon a pile on the railroad car, and then returning for reloading. One of Taylor's assistants supervised and timed the procedure, telling Schmidt when to bend, when to walk, at what pace, etc. Schmidt's output rose to an amazing 47½ tons per day. Several other men were similarly trained, and these, likewise, attained the unprecedented output.

This experiment yielded some interesting conclusions. An analysis was made to find if there was any close relationship between the energy expended by the men and the tiring effect. It was clearly demonstrated that the men carrying nearly 48 tons were no more fatigued than the men who moved only 12½ tons using the old method. From a physiological point of view, Taylor stressed that a man standing still holding the 92-pound pig gets equally, if not more, tired than a man walking with this same load.

It was further observed that there was an optimum in the weight of the work load. When pigs weighing 92 pounds were being handled, a first-class worker could be under load only 43 per cent of the work day. The remaining 57 per cent of the time was needed for the return

trip for reloading and for rest periods. When the load consisted of only a half pig, weighing 46 pounds, the worker could be kept under load 58 per cent of the time. This variance meant that a careful study of all pertinent variables was mandatory before work methods and standards could be set for increased efficiency.

From the accumulation of statistics, Taylor concluded that a pig-iron handler, walking on the level, should move at the rate of 1 foot in 0.006 minute. Since the average distance from the stockpile to the car was 36 feet, the average time under load per pig was about 0.22 minute. On the basis of a ten-hour day, during which the worker could be under load 43 per cent of the time, this meant that there were 258 minutes for being under load. This sum, 258 minutes, divided by the time required to move one pig, 0.22 minute, indicates that one man could move approximately 1,173 pigs per day, or a total of almost 108,000 pounds.

Taylor also stressed that in the selection of the proper worker for a given type of work, physical and mental characteristics must be carefully considered. A mentally alert and intelligent individual would undoubtedly be entirely unsuited for the monotonous and unchallenging task of handling pig iron. Only 1 man out of 8 of the original gang proved to be suited for this class of work. The individuals unsuited for the operation were eventually removed and placed in positions for which they were physically, mentally, and emotionally better qualified. Thus Taylor demonstrated that better selection and training of workers was conducive to improved performance.

QUESTIONS

1. Taylor had hoped to be able to determine a standard for manpower comparable to the measure of mechanical energy termed horsepower. What are some of the deterrents to such measurement?

2. Upton Sinclair, author of *King Coal, The Jungle,* and similar social-reform literature, was most vociferous in his denunciation of Taylor's scientific exploitation of the worker. In particular, he was emphatic about the inequity of a fourfold increase in output being rewarded with a 60 per cent increase in pay. How would you refute Sinclair's argument?

3. What handicap currently would impede a management from introducing a new method which would result in the displacement of 7 out of 8 workers?

4. On the basis of the data presented in this illustration and discounting the element of fatigue, which work load, a 92-pound pig or a 46-pound pig, would give the best results as to:

a. Foot-pounds of product moved per man-day?

b. Direct-labor cost per man-day?

c. Total time required to transport the entire stockpile?

5. How would a reduction from a 10- to an 8-hour day with no commensurate decrease in pay affect:

a. Total output per man-day?

b. Direct-labor costs for this operation per ton?

6. If the distance the pig iron was moved was shortened to 25 feet but the angle of the elevation of the plank was changed from 0 to 15 degrees, what effect might this have upon performance? Use estimated figures where necessary to show your conclusions arithmetically.

ILLUSTRATION 2. Taylor's Shoveling Experiment

Taylor applied the same analytic technique to the study of other work situations. His demonstration of what he termed the "science of shoveling" was one of the most convincing arguments in favor of scientific management. This illustration was presented in testimony before a House Committee investigating Taylor's and others' systems of shop management. The occasion for this investigation was the realization by our lawmakers that America's capacity to produce had to be increased because of the imminence of World War I.

At the Bethlehem Steel Company, there were approximately 600 shovelers engaged in moving various raw materials and waste products. Each shoveler owned his own shovel, consequently there was a great variety of shapes and sizes. At times a worker was dispatched from the shoveling of one item, for example, iron ore, to work upon a different material such as rice coal, limestone, or ashes. Thus the same shovel was used for a 30-pound load of iron ore and for a 4-pound load of rice coal.

Taylor and his associates made thousands of stop-watch observations. They observed the motions, for example, employed when pushing the shovel into the pile of material. The times and the motions used in swinging the shovel backward and in throwing the load forward were studied for varying heights and distances. The effects of shoveling on a dirt bottom, or on wood or stone bottoms, were also noted. Many other variables were carefully observed.

As one of the recommendations of this intensive analysis, it was determined that there was an optimum weight per shovel load regardless of the material being handled. This optimum weight was 21 pounds. Although it is obvious that no shoveler can consistently measure an exact 21-pound load, a variance of 3 or 4 pounds either way would probably average off and thus not affect the results appreciably. Instead of the myriad types and sizes of shovels, the Bethlehem Steel Company installed a central shovel tool room where some 8 to 10 different shovels were available, each for a specific material. This practical consideration resulted, in the third year of trial, in an increase in the average number of tons shoveled per man per day from 16 to 59. For this, the workers' pay was raised from $1.15 to $1.88 per day. The

number of yard laborers was reduced from about 600 to 140. Average cost of shoveling a long ton dropped from \$0.072 to \$0.033. On a total volume of materials handled, measured in millions of tons, the total annual savings was evidently significant.

QUESTIONS

1. Assuming that the shoveler was under load 70 per cent of the time and rested 30 per cent of the time, in a 10-hour shift:
   a. How many shovelfuls did he throw?
   b. What is the average time per shovel throw including loading time?
2. If the work day were reduced to 8 hours and wages remained at \$1.88 per day and productivity rose by 5 per cent, what would be the cost of handling per long ton?
3. Why would this type of work present a fertile field for mechanization?
4. Assuming a total annual cost for capital equipment equal to 25 per cent of the initial purchase price, about how much equipment would be purchased per million tons of product handled if labor costs were completely eliminated?

ILLUSTRATION 3. Advent of Professional Managers

The human side of the business, as well as the efficiency of the plant, was developed greatly during my lifetime. If the old steelmasters could come back to life today and see all our public relations departments, not to mention our management-labor negotiations, they would be terribly shocked.

The oldtimers put on a sort of one-man show. They were operating men, geniuses of production. They had little use for anybody who did not know how to make coke, run a blast furnace and form steel. They regarded their accountants and lawyers as a necessary evil, to be paid as little heed as possible. Even when financial necessities forced them to incorporate and set up a board of directors, they regarded the directors as a bunch of prying interlopers. They hated unions and paid no attention to the public. They responded to criticism by asking, "What does the public know about making steel?"

I do not mean to be critical of them. After all, they created the industry. Whatever one might think of their methods, these methods worked at the time and got the ball rolling. The old U.S. steelmasters did a better job of getting our industry off to a solid start than did their counterparts in Britain, France, Russia or anywhere else. It is unfair anyway to judge men who worked a half century ago by the standards of today. I rather imagine that our present generation of businessmen, me included, will look old-fashioned and shortsighted 50 years from now.

But I do take great pride in having been a part of today's type of corporation management and perhaps in having helped to mold it a little. The trouble with the oldtime management was that it was just a little too individualistic. Practically every company started with some outstanding individual. He founded the company, built it and ran every aspect of it with an iron hand. When he died the company usually died with him, for none

of the heirs could fill his shoes. In my time I have seen dozens of companies go downhill in this fashion, and often whole cities with them. Their downfall was sealed the day the founder died, or sometimes when he just got so old that his judgment was impaired.

Somebody finally got the idea of hiring professional managers to replace the lone wolf genius who had bequeathed the company to his heirs. Thus was born the modern idea of corporate management, and thus was an opportunity given to people like me who were outsiders, often humbly born and not members of the clan. Modern management, with its professional attitudes, its concern for the public welfare and public relations and generally humane attitudes toward business, is far better than the old system. Some critics—*Fortune* magazine is one of them—deplore the fact that all businessmen today seem to be modest and polite duplicates of one another instead of flamboyant "characters" as in the old days. But you cannot have it both ways, and today's Man in the Gray Flannel Suit is ten times more efficient than his more colorful, more hot-tempered predecessor.[8]

QUESTIONS

1. What arguments, in addition to those presented by Benjamin Fairless, could be advanced in defense of the "one-man show" put on by the old steelmasters?
2. What evidence might Fairless advance in justification of his final statement?
3. Since history demonstrates that "practically every company started with some outstanding individual," does the replacement of this type of entrepreneur by professional managers foreshadow a decline in industrial dynamism?
4. Mention some instances where the death of a corporation's founder has resulted in the decline of the company and, perhaps, even of the community.

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CHAPTER 3

Technological Change

DEFINITION AND DESCRIPTION

Technology, as used in this text, pertains to the science and art of producing and distributing economic goods and services. It is synonymous with industrial know-how and refers to the manner in which the available means of production are utilized. The term *production* was previously defined as the creation of utility. Since there are numerous ways in which the ingredients of production can be combined to create utility, it is evident that there can be many different technologies. A specific technology is invariably the culmination of an evolutionary process. The direction this evolution takes depends upon a great many forces, a large part of which are noneconomic. Figuratively speaking, a technology embodies the manufacturing mores of a given society. These customs of production do change, but the changes generally occur slowly and sporadically. Before an analysis of the forces instrumental in fashioning our present technology is presented, it is necessary to explain a number of pertinent terms.

Value Added. The objective of economic activity is to increase the supply of goods and services available for the satisfying of human wants. Because there are numerous ways in which the productive factors can be combined, it is important that we have some acceptable measure to indicate the relative effectiveness of the various combinations. The concept of value added provides the best yardstick for this purpose.

In brief, value added is the differential between the cost of the materials and supplies purchased and the value of output. Thus value added represents the contributions of all the factors of production minus the cost of items which have been formed and made available by other enterprises. In a recent year General Motors Corporation had a sales volume of nearly $12 billion. However, in that same year General Motors purchased about $6 billion worth of materials from suppliers. Thus the value added by General Motors in that specific year was only about $6 billion. The logic is obvious—the value of the materials provided by independent suppliers represents the value added by these enterprises and should not be double-counted in the calculations of the value added of all subsequent purchasers of the material.

Considering that a corporation such as General Motors has a value-added ratio equal to only about 50 per cent of the total value of sales, attention should be focused upon the concept of integration. Obviously, a manufacturer engaged solely in a finishing operation, such as final assemblying, has a much lower ratio of value added to total value of sales than does an integrated manufacturer engaged in several stages of the production process. The complexity of these various operations, together with the quantity and quality of manpower and machine power, also affect the value added.

Although this concept is the best measure of relative economic contribution, it does have some serious limitations. Both utility, the ability of a good or service to satisfy a human want, and value, the power of a good or service to command other goods or services in exchange, are closely linked with psychological impulses. There is no "valuemeter" comparable to a thermometer or barometer with which value judgments might be accurately measured. Even the monetary units generally used to designate value are subject to inflationary and deflationary forces. Although these and other limitations impede the more scientific measurement of excellence in performance by means of the value-added concept, it is nevertheless the best yardstick for measuring the relative contributions of all enterprises.

Integration. *Vertical* integration consists in the performance by a single manufacturer of more than one of several successive stages of operation required to complete a product. (1) *Backward* vertical integration pertains to the undertaking of more and more preliminary stages, at times even reaching into the raw-materials-extraction phase. The operation of coal mines by steel producers and of cement mills by construction firms are typical examples. (2) *Forward* vertical integration designates the incorporation of additional phases of operation

by which a product is made more complete or is brought closer to the consumer. Service stations run by petroleum-refining companies and financing services provided by automobile manufacturers illustrate this variety of integration.

Horizontal integration consists in the duplication of production facilities, necessitated either by technological or geographic considerations. Chains of retail stores and automobile-assemblying plants located in various parts of the country typify this form of integration.

Circular integration, a catch-all category, which might be more properly considered as diversification, results in the undertaking of activities not directly related to the company's major line of products. Circular integration manifests itself in a number of forms since it arises from a variety of causes. When a plant has excess capacity, it is generally feasible to attempt making other products with the available facilities. However, since these facilities are fixed, the process and the raw materials used to make the new products tend to remain unchanged, as in the manufacture of farm equipment and household equipment by auto makers.

Another form of circular integration occurs when a company decides to utilize by-products. In this case it must frequently install entirely new equipment and use new processes. The manufacture of fertilizers by meat packers is an example. Finally, when a manufacturer decides to balance his product mix to minimize the depressing effects of a decreased demand for a specific commodity, he generally decides to add an item completely unrelated to the present line. This form of integration is illustrated by General Mills, a food-processing company which entered into the making of chemicals, machinery, electronic and precision equipment, and, for a while, of home appliances. The three types of circular integration are not always easy to differentiate since they vary only in degree of proximity to the company's basic line of products.

Integration is rather closely connected with technological change. For example, competitive pressures make it mandatory that most industries minimize the waste of materials by converting scrap into useful by-products. High overhead costs force companies with idle capacity either to dismantle the excess facilities or to adapt them to the making of other products. Almost without exception, large corporations have recognized the hazards attached to concentration in a single line of products. Thus circular integration is born of technological necessity. The advantages of national marketing and, on the other hand, the high costs of transportation have resulted in the establishing of regional plants by practically all large-scale enterprisers.

Technological factors make horizontal integration mandatory for most large corporations. Similarly, technological forces impel many concerns to integrate vertically to ensure a supply of high-quality raw materials at a minimum cost.

Production Methods. The method used in the production of a specific commodity is very closely connected with the prevailing level of technology. Production methods can be classified as to (1) function and (2) sequence.

1. The *functional division* includes the following processes:

a. The *analytic* process is that in which the raw material is broken down into its component parts, as in meat packing and oil refining.

b. The *synthetic* process is that in which several semifinished components are joined to form a more complete item. All assembly-type operations are synthetic in character.

c. The *conditioning* process consists in the application of physical, chemical, or electrical action upon a material so that its appearance or physical properties are modified.

d. The *extractive* process is simply the moving of a natural resource from its original location and making it ready for further processing by one of the preceding methods.

2. Production methods classified as to *sequence* are the following:

a. Continuous production is typified by industries such as chemical, paper, and sugar processing, in which the materials move sequentially and steadily through the materials-handling system from one production center to the next in an unceasing flow. Operations are halted only for machine repairs or when a serious lack of orders occurs.

b. Repetitive production resembles continuous production in that the materials-handling system is fixed and must be capable of moving large quantities. Technological factors, however, allow much more flexibility in the length of the operating cycle, the sequence of operations, and the continuity of the process.

c. Intermittent production is used whenever the variety of products, special processing requirements, or relatively small orders place a premium upon flexibility. The materials-handling system cannot be fixed permanently in any given arrangement since the sequence and duration of operations are quite variable.

It is evident that the choice of production method, on a functional or sequential basis, is largely determined by technological considerations. In practice, most industries do not restrict operations to a single process but combine methods as the technological requirements demand. Because technology imposes such rigid limitations in the

choice of production methods, there is no point in enumerating the advantages and disadvantages of each method. However, it should be evident that the repetitive and continuous processes are conducive to mechanization, specialization, standardization, and mass production. The imperativeness of a smooth product flow does, in turn, impose serious restrictions. High equipment costs make production delays disproportionately costly. Careful scheduling and routing are important if bottlenecks are to be minimized. These and related aspects will be further considered in the chapters treating of production techniques.

DEVELOPMENT

Technological changes have been taking place ever since the Stone Age, whose three main periods, Eolithic, Paleolithic, and Neolithic, are differentiated by the manner in which stones were fashioned into implements. In the Eolithic period, man used sharp stones as he found them fashioned by the elements. During the Paleolithic period man improved upon nature by chipping the stones into better tools. Then, in the Neolithic period, superior stone implements were fabricated after grinding and polishing techniques had been perfected.

A detailed analysis of the evolution of technology is patently beyond the scope of this text. However, it should be pointed out that the progression of civilization from the Stone Age, through the Bronze and Iron Ages, into the present era has been characterized by a close correlation with the prevailing industrial know-how. Better tools and better production methods have been responsible for material well-being and sociopolitical advancement.

Reference has already been made to the contributions of several ancient civilizations to industrial progress. In each instance some measure of inventiveness, or at least of innovation, was manifest. Most of these contributions, however, were simply modifications or combinations of the so-called basic simple machines: the screw, the wedge, the wheel and axle, the lever, and the pulley. The Greeks were by far the outstanding inventors of the ancient world. They projected their philosophical inquisitiveness, their spirit of speculation, to the practical application of machines in the performance of onerous tasks. Giedion states[1] that Hero of Alexandria "built and improved oil presses, fire fighting pumps; invented lamps with automatically advancing wicks, and water tube boilers for heating baths. . . . The Alexandrian inventors (third and second century B.C.) were masters in

[1] Siegfried Giedion, *Mechanization Takes Command,* Oxford University Press, New York, 1948, pp. 31–32.

combining the so-called simple machines . . . powered by combinations of water, vacuum or air pressure to carry out complicated movements or manipulations."

The Greek men of science were especially prolific in the area we have termed pure research. They made a host of discoveries which gave impetus to the development of the sciences of mathematics, physics, and chemistry. Without this progress the "practical" inventions might have taken considerably longer in appearing.

There is a hiatus of nearly 2,000 years between the contributions of the ancient Greeks and the inception of the Industrial Revolution. During that interval, improvements were made upon most of the basic industrial techniques such as metalworking and textile spinning and weaving. Even in the Dark Ages, after the disintegration of the Roman Empire, technological improvements continued to be made. However, it was not until the middle of the eighteenth century that the tempo of change was accelerated at so tremendous a rate that the period came to be known as the Industrial Revolution.

The first indication of the new attitude was manifest in the textile industry. The hand loom then in use had not been modified for at least a thousand years. The crude spinning wheel had, likewise, been changed very little since its introduction late in the Stone Age. In 1738 John Kay, a Lancashire weaver, built the flying shuttle, a semi-automatic spring-propelled device which carried the weft thread back and forth between alternate warp threads. The relative automaticity of this shuttle resulted in a greatly increased weaving capacity and an imbalance between spinning and weaving capacities. Foresighted men almost immediately began to rectify this situation by inventing better spinning equipment. In 1764 James Hargreaves perfected his spinning jenny. At first this jenny turned 8 spindles. In a few years Hargreaves had perfected his spinning mechanism so that it motivated 80 spindles at one time. Additional improvements in spinning equipment, such as Richard Arkwright's water frame and Samuel Crompton's spinning mule, soon made it mandatory that significant changes again be made in the weaving machinery. This led to the introduction of the power loom by Edmund Cartwright in 1787.

These developments in the spinning and weaving divisions of the textile industry had to be matched by comparable improvements in the techniques of production of textile raw materials. Eli Whitney's cotton gin, successfully demonstrated in 1794, was the solution to the equilibration of textile raw materials and manufacturing capacity. This competition in the technological competence among the several

divisions of the textile industry stimulated gadgeteers and theorists and helped reawaken the spirit of inquisitiveness which had remained quiescent since the era of the Greek philosophers.

Almost simultaneously, the technological changes in the textile industry were accompanied by comparable improvements in other fields. Coal, first used as a substitute for charcoal in industry by a blacksmith, Dud Dudley, in 1619, was finally adopted as the basic fuel in iron smelting around 1710. The first air-blast furnace was built by John Smeaton in 1760. Peter Onions and Henry Cort discovered the puddling process for making a superior malleable iron in 1783. French watch and clockmakers made significant improvements in cutting tools, particularly in screw-cutting lathes. In 1775 John Wilkinson improved upon the French machinist's contribution by inventing a boring machine which produced cylinders up to 50 inches in diameter with deviations no greater in any part than "the thickness of an old shilling." With this and comparable advances in machine tooling, new horizons were opened to technological advancement.

Of all these innovations, probably the most significant, because of the many areas in which it could be used, was the development of a steam engine with industrial potential by James Watt, around 1765. It should be noted that steam engines were in use prior to Watt's invention. The discovery of the principle of the steam engine dates back at least to 100 B.C. when Hero of Alexandria rigged a device for opening and closing temple doors by means of steam power. This idea was revived in the sixteenth and seventeenth centuries and led to the construction by Denis Papin of the steam digester about 1690.

Papin even anticipated Robert Fulton's application of steam to the propulsion of water-going vessels by more than a century. In 1697 Papin demonstrated his idea by propelling a model boat with one of his steam digesters on the River Fulda in Germany. However, the elector of Hanover refused him the freedom of the rivers, and a mob of river boatmen, fearing the possibilities of the steamboat, destroyed the vessel and tried to kill Papin, who barely escaped to England.

In 1705 Thomas Newcomen introduced an atmospheric engine which had some limited industrial use. This engine, with an automatic device for opening and closing the steam valves in the process of raising the piston, condensing the steam, and allowing the atmosphere to return the stroke of the piston, was the real progenitor of Watt's steam engine. While repairing a Newcomen engine, Watt observed the tremendous waste of fuel and energy due to the excessive and repeated

heating and cooling of the cylinder. He came upon the idea of closing both ends of the cylinder and applying steam to force the piston back and forth in the cylinder.

With the introduction of a source of power which could be moved to any location, industry was freed from the dependence upon water power for motivation. In addition to mobility, the steam engine provided a more controllable, a more powerful, and a more dependable source of industrial energy. Concomitantly, the acceptance of the steam engine stimulated technological improvement in many industries, particularly in coal mining and metal working. Although human, animal, and water power had long been used to motivate simple machines, it was the steam engine which ushered in the era of mechanization.

COROLLARY 1. Mechanization

In its broadest sense, mechanization is the use of any tool or piece of equipment to aid human effort. Generally, before mechanization can take place, it must be determined that the specific operation is (1) divisible, (2) repeatable, (3) routine, and (4) frequent. Closely connected with the process of mechanization are the principles of division of labor, specialization, standardization, mass production, and transfer of skill. The latter is the basis of all mechanization. As a greater and greater portion of the work is transferred to the machine, the requisite degree of worker dexterity and physical and mental application usually tend to diminish. This worker-skill factor in the actual performance of the production job approaches a minimum with automation. It should be emphasized, however, that as the machine assumes certain worker skills, the machine tender frequently is transformed into a higher-quality worker, skilled in the engineering aspects of his job.

Not only does mechanization consist in the utilization of machines, it also relates to the use of organization and operating methods. This latter aspect is important since it pertains to the integration of mechanical appliances into the industrial system so that they are economically and socially acceptable. History records numerous instances where inventors of new mechanisms failed in their attempts to convince industry of a machine's practicability. Even more difficult for them than demonstrating the economic value of a particular piece of equipment or manufacturing technique is convincing the workers and the public of the social value consequent to such change. This difference of opinion as to the social value of mechanization has precipitated numerous virulent attacks and debates involving both theo-

rists and practical individuals. Typical of such polemics is the classic dispute between two leading nineteenth-century French economists, J. C. L. S. de Sismondi and J. B. Say. The former maintained that overproduction was brought on by the "superabundance of capital equipment aggravated by the too powerful assistance which science has given to the useful arts." Thus technological change was the direct cause of the glutting of the market with a quantity of goods which the public was unable to consume. The result was the inevitability of depressions. J. B. Say disagreed, contending that commodities supplied demands for each other and that every time a new product was made it immediately generated new demands. If every producer brought more goods into existence, he would receive more of other people's products in exchange. Consequently, it was lack of production rather than overproduction which caused depressions. If this view were correct, then technological change would be the best safeguard against economic slumps. Sismondi's condemnation of rapid technological advancement is echoed even today in statements that the worker is steadily becoming more and more an adjunct to or a servant of the machine.

The negative attitude shown by many spokesmen of trade-union groups toward the advanced mechanization, currently labeled automation, is reminiscent of the feelings expressed by workers during the early days of the Industrial Revolution. The revolt of factory workers between 1811 and 1816, inspired by a half-wit named Ned Lud, culminating in the burning of factories, smashing of equipment, and beating of operatives using the new machines, is a single example of the antagonistic attitude shown in the early days of mechanization. Certain union restrictions upon the use of laborsaving devices parallel the Luddite hostility to progress. This reference to opposition by some union leaders to technological change is certainly not typical of all labor officials. Philip Murray, while president of the CIO, emphatically stated that he did not know of a solitary instance where a great technological gain had actually thrown people out of work. The United Auto Workers has been outstanding in its acceptance of mechanization. The classic 1948 contract with General Motors Corporation in which wage increases were tied in with gains in productivity specifically stipulated that the auto companies had a free hand in introducing any technological changes. The United Mine Workers of America has, likewise, been most favorably disposed toward the introduction of laborsaving devices such as coal-cutting machines, mobile loaders, and a variety of continuous mining machines such as the Joy Manufacturing Company's Coal Mole.

The forward-thinking labor leaders recognize that mechanization, although it frequently results in the dilution of some skills and the obsolescence of others, generally means a lightening of the work load, an improvement in working conditions, an increased pay resulting from higher productivity, and an upgrading in the job levels. Invariably, union leaders insist that the gains resulting from the increased productivity be shared equitably. In some cases suggestions have been made that a "technological sharing fund" be set up whereby a portion of the money saved through labor-replacing devices would be used to retrain or to retire the technologically unemployed.

At times technological displacement can assume significant proportions. In the telephone industry approximately 50,000 operators have been displaced by dial conversions. Fortunately, the growth in this industry has more than offset the displacements arising from technological improvements. The use of business machines has enabled concerns such as the Connecticut Mutual Life Insurance Company to reduce the number of people needed to handle each $100 million of insurance from 33 employees in 1949 to 25 employees in 1955. A single Univac computer, used by the Metropolitan Life Insurance Company, replaced 100 punch-card machines and displaced 125 punch-card operators. In some instances serious problems are posed by the downgrading of jobs as the result of mechanization. For example, the recent introduction of the new "hide puller" machine in the meat-packing industry replaces the floorsman, the most highly skilled and highly paid man in the beef-killing room. The new machine, operated by a semiskilled worker who makes a single cut in the breast of the animal, strips away the entire hide from the carcass without cutting the skin. The introduction of this machine is said to have boosted production by 20 per cent per man in the killing room.

The beneficial effects of technological change can be readily observed in two specific instances, the bituminous-coal and cotton-agricultural industries, which have only recently embarked upon large-scale mechanization programs. In the bituminous-coal industry, a little more than a quarter of a century ago, pick-and-shovel mining was quite common. As late as 1940, less than one-seventh of the total coal output was loaded by machinery. Currently, of all underground mined coal, more than 80 per cent is mechanically loaded and more than 90 per cent is mechanically cut. The introduction of several types of continuous mining machines portends an even more intensified mechanization. By 1956 several hundred of these continuous mining machines were in use, accounting for nearly 5 per cent of the industry's output.

Most revolutionary of the continuous mining machines is Union Carbide and Carbon's remarkable auger-type robot. The carbide-tipped cutting wheels of the machine are operated by remote control. Two feeler cams on the outer edges of the cutting tool send electric impulses back to the control station. These impulses, as shown on oscilloscope tubes, indicate the hardness of the substance being cut. The operator can readily guide the machine into the relatively soft coal seam. This technique permits cutting $3' \times 10'$ holes, 1000 feet long, without timbering, trackage, rail equipment, lighting, ventilating, or other safety requirements. Whereas other continuous mining machines require ten or more men at the working face, the auger-type robot needs only three men, none of whom are within the mine.

Even under the present mining system, where plant layout is not very favorable to the continuous mining technique, production up to 50 tons of coal per man shift is claimed. In mines where the continuous mining machinery is not handicapped by old-fashioned layout and transportation, it is contended that the new automatic equipment can be utilized 60 per cent of the total working hours. This is in contrast to the 25 per cent of total time that conventional machines are in active use in present mining operations. This significant improvement in the capacity factor (the ratio of average use of facilities compared with potential use) should have favorable results on productivity and profits.[2]

Other relatively recent technological changes include extensible belt conveyors, mechanical cleaning, large-scale strip mining, underground gasification, and hydrogenation. Associated with these technological changes and intensified mechanization is a steady rise in productivity. In 1930 the output per man-hour on a portal-to-portal basis averaged 0.550 ton. By 1959 this average had been raised to more than 10.85 ton per man-hour, more than four times the British and three times the West Germany rate of output. This significant rise in productivity has had several concomitants. The labor force has dwindled since the mid-twenties from more than 700,000 to approximately 250,000 miners. On the other hand, the average hourly rate of pay has risen sharply. The $3.20 average hourly earnings paid coal miners in November, 1958, was among the highest rates paid American workers, comparing very favorably with the $2.02 average hourly pay for factory workers.

Another outstanding example of the continuing progress in mechanization can be seen in cotton agriculture. In 1926 about 45 million acres was dedicated to growing cotton in the United States. At present less than one-third that acreage is used for growing cotton, yet the total output, approximately 13 million bales, has not declined. This change has been brought about through a progressive increase in

[2] Stanley Vance, *American Industries*, Prentice-Hall, Inc., Englewood Cliffs, N.J., 1955, pp. 26–28.

yield from 193 pounds per acre in 1926 to 450 pounds per acre in 1957. This gain can be attributed to improved farming methods, especially mechanization and the use of fertilizers. Mechanical cultivators, flame throwers to destroy weeds, airplanes for dusting against insects and disease, and mechanical pickers are widely used. The last, introduced in 1942, have been particularly fruitful. With a machine of this type, 200 acres of cotton can be harvested in a season. A single machine does the work formerly performed by a crew of 70 pickers, harvesting a bale of cotton with an expenditure of only about 4 man-hours, whereas formerly 100 man-hours was required by the hand method. Harvesting costs, despite the sizable initial capital investment, have been cut by as much as $50 per bale.

These instances of progress through mechanization have been paralleled in many other industries. The net result, as has already been described in the previous chapter, has been a dynamic progression in productivity.

COROLLARY 2. Electrification

The remarkable strides made in mechanizing industry would not have been possible without the development of electric power. Just as the introduction of the steam engine ushered in the Industrial Revolution, so electrification made possible the progression into the highly complex field of automation. The correlation between electrification and industrial progress is patent in the steadily increasing use of electric power in industry. In 1920 the average manufacturing worker annually used 3,155 kilowatthours to help him get his work done. By 1954 this consumption had risen to 17,900 kilowatthours, the equivalent in human energy of 250 assistants. Average domestic consumption of electric power, which increased during the same period from 339 to 2,550 kilowatthours, reflects the same trend. The average housewife now has an electric-power energy equivalent to more than 36 servants to assist her in her chores. A fully electrified home, using about 30,000 kilowatthours annually, would have the equivalent of 450 servants.

The combined industrial and domestic consumption of electricity has increased markedly in recent years, rising from 74 billion kilowatthours in 1925 to 333 billion kilowatthours in 1950. The National Security Resources Board in its 1952 report estimated that by 1975 total demand would reach 1.2 trillion kilowatthours. Installed generating capacity, which increased from 51 million kilowatts in 1940 to 97 million kilowatts in 1950, should, at the present rate of increase, exceed the 200-kilowatt capacity mark by 1965. In the twenty-year

period after 1939, sales of generating and transmission equipment increased nearly tenfold. At present about 60 per cent of the total output of electricity is consumed by industry. The aluminum-reduction industry, with an average annual consumption of about 1,400,000 kilowatthours per worker, is by far the leading industrial user of electrical energy. Other leading industrial consumers on an average annual kilowatthour-per-worker basis include iron and steel, petroleum, paper, chemical, and zinc, with averages of 27,000, 38,000, 40,000, 42,000, and 135,000 kilowatthours, respectively.

The increased use of electricity in industry has been accompanied by many significant technological changes such as the large-scale usage of individual motor-driven machines. This particular technological improvement permits rapid relocation of equipment without making elaborate changes in the power-transmission lines or the power source. Flexibility in plant layout and in machine utilization is the net result. Prior to the technological developments in electric motors for individual machines, belt drives were universally used in industry. Although this method is even today usable, particularly in industries where flexibility is not imperative, the availability of smaller motors for individual machines has given impetus to continued mechanization. Equally important are electrical controls which are used for regulating machine speed, position, load, direction, temperature, and many other variables. Without such electrical controls, industrial machinery would not have attained such high degrees of quick response, high accuracy, and sensitivity. There are numerous aspects of electrification which are worthy of further consideration but which cannot be more thoroughly analyzed because of space limitations. The importance of electrification, however, should be evident from the foregoing and from the subsequent description of automation, the most recent development in the field of electromechanics.

COROLLARY 3. Automation

The term *automation* has a variety of meanings. "Detroit automation," as envisioned by Delmar S. Harder, the Ford Motor Company executive vice-president who, in 1947, first described the concept, pertains to the mechanized transfer of work pieces between work stations where successive tasks are performed upon the product. Among the various connotations of automation are:

1. The control of machines by nonhuman means such as magnetic tapes and punched cards.
2. The use of electronic devices, and specifically digital computers, in production.

3. A philosophy of systematic work organization where the processes and equipment are subject to mathematical controls such as statistical quality control, linear programming, etc.

4. An advanced technological change involving such mechanisms as transfer machines.

5. A continuous and automatic operation employing feedback control. This feedback aspect is assumed by many production specialists to be the essence of true automation. The following is a summary description of this version of automation.

Feedback has been defined as part of a closed-loop control system which brings back information about the condition under control for comparison with the target value. The term *closed loop* refers to automatic control units linked together with a process to form an endless chain. There is a constant measuring of the control action by the unit itself so that deviations from the desired objective are automatically corrected. It is largely this self-correcting action which differentiates automation from the more advanced forms of mechanization. The principle of thermostatic control has frequently been used to illustrate the principle of the closed-loop system and feedback. The heat-sensitive control reacts to heat and cold stimuli through expansion and contraction and relays this information through an electric circuit to the heating mechanism. The self-regulation hinges upon the differential gap or the variance between the upper and lower control limits. Thus, for example, a thermostat set at 72°F might have an upper limit of 73°F, at which point the heating unit shuts automatically. Conversely, if the lower limit has been set at 71°F, that is the point at which the heater is activated. This range of 2°F is the differential gap.

An analogy is sometimes made between the human nervous system and feedback. The manner in which an individual guides his hand in reaching for an object, sometimes missing the mark but maneuvering until attaining the goal, is analogous to the feedback functions. The fire-control systems used in military aircraft are a good example of the application of this principle. In the industrial application of the feedback system, information concerning the actual performance of an operation is continually compared with the desired result. If performance deviates beyond a permissible margin, action is taken automatically to correct this deviation. Thus automation requires these basic components:

1. Sensing devices that react to changes in volume, quality, voltage, and other measurable qualities.

2. Computers which receive the information and process it according to criteria set by the operative.

3. Actuators which respond to the "orders" as concluded by the computers. This actuation consists in the moving of gears and tools, the closing and opening of valves, and similar actions. Limit switches of various types are an integral part of most actuating devices.

4. Transfer mechanisms are essential for most manufacturing and assemblying processes which are automated. These transfer machines consist of a series of machine tools mounted on a common bed with a common device for transferring parts progressively through the machine as the various operations are completed.

Paul Lindholm of the Western Electric Company has very effectively summarized the more important aspects of this subject in his presentation relating to the six elements of feedback control.[8]

1. *The command* is the physical determination of the desired value of the measured-process variable. It involves setting a pointer, turning a knob, etc., to a value that corresponds to the condition you want to maintain. Command can be manual or automatic (as part of another control system).

2. *Disturbance* is the physical change of some factor in the process (or external to it) that causes a change in the measured-process variable. On a controlled motor, for example, disturbance may range from an increased load or drop in line voltage to a change in ambient temperature.

3. *The reference input element* is a physical device that receives the command and translates it into a signal or position that can be measured or detected by the summing point.

4. *The summing point* serves two functions: It compares the measured or detected information from the reference input element with measured or detected information from the controlled system. It generates an actuating signal, based on the difference of the two compared measurements, and transmits it to the control element.

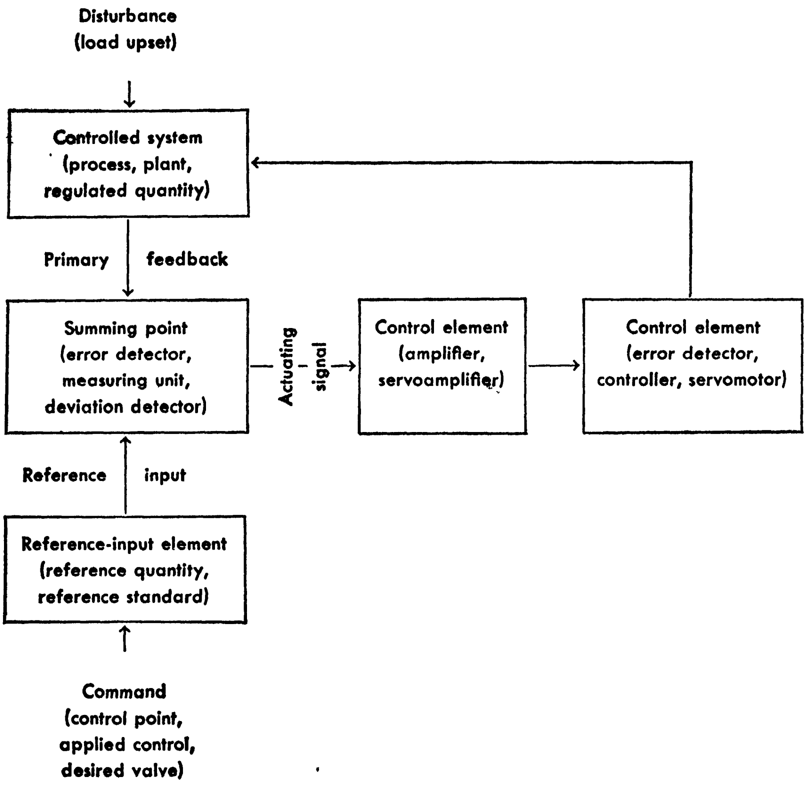
5. *The control element* has two functions, first to amplify the actuating signal, and then to use that amplified signal to change some factor affecting the controlled system.

6. *The controlled system* is the process or operation some measured variable of which is to be regulated. The control loop is "closed" by a primary feedback signal (another "translation" of measurement) from the controlled process back into the summing point.

[8] Paul Lindholm, "'Feedback'—Heart of Automatic Process Control," quoted in L. R. Bittel, M. G. Melden, and R. S. Rice, *Practical Automation*, McGraw-Hill Book Company, Inc., New York, 1957, p. 44.

The control element changes the controlled system until it matches the reference input element. Any variable may be regulated, such as speed, frequency, temperature, position, torque, direction, and voltage. Similarly, any unit of measurement may be used as a reference standard.

Exhibit 3-1. Elements of a Feedback Control System



SOURCE: Paul Lindholm, " 'Feedback'—Heart of Automatic Process Control," quoted in L. R. Bittel, M. G. Melden, and R. S. Rice, *Practical Automation,* McGraw-Hill Book Company, Inc., New York, 1957, p. 44.

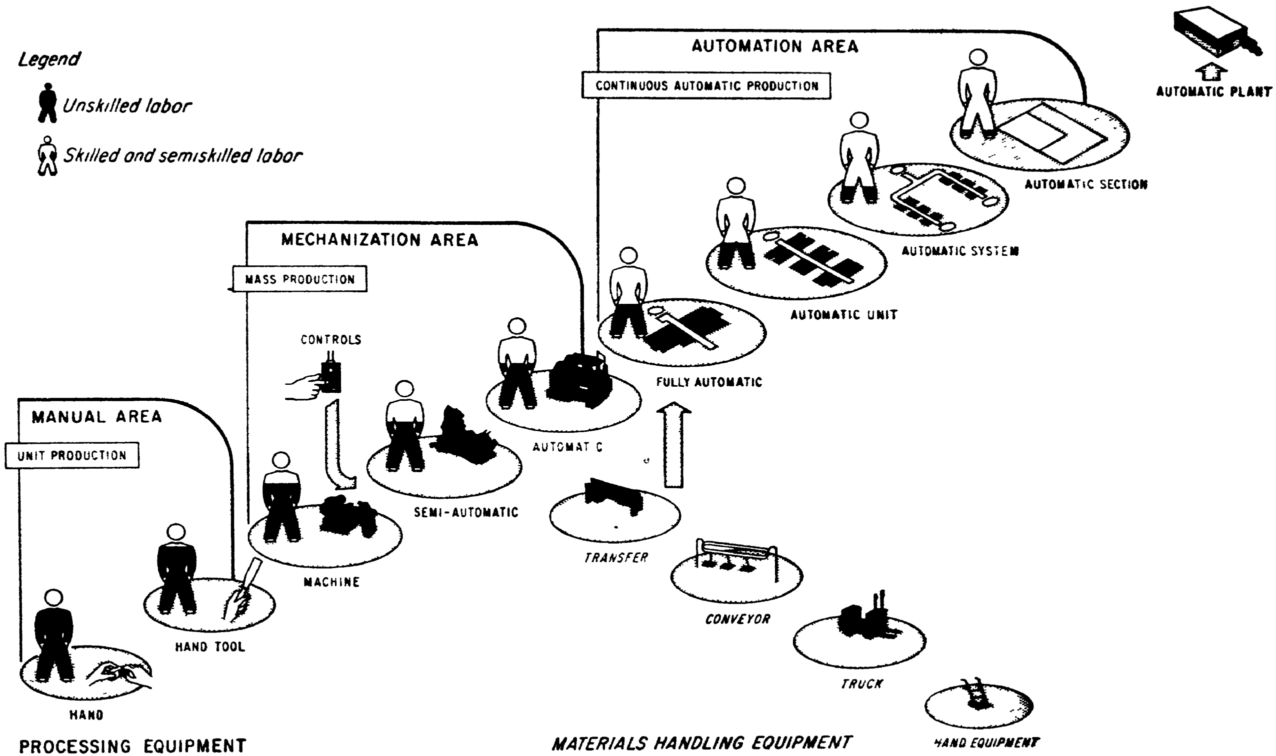
Another view of the feedback process so vital to automation is presented in Exhibit 3-1. The six elements identified in initial capital letters are the terms proposed as standard nomenclature by the American Institute of Electrical Engineers. The other terms, in parentheses, are common alternatives.

Obviously, automation as thus described is not commonplace in industry. True automation goes considerably beyond mechanization in so far as it removes human watching, thinking, and reacting from routine machine operations connected with the handling, making, inspecting, assemblying, testing, and packaging. Unfortunately, there is considerable confusion in terminology, and what sometimes is referred to as automation, upon closer inspection turns out to be merely a more advanced form of mechanization. This is particularly so in many of the glowing accounts of automation in the metal-working industries. For example, the Cross Company's Transfermatic, designed to process V-8 cylinder blocks, consists of 104 operating stations integrated into one complete production line. In addition to 555 machining operations, it performs 133 inspections and automatically marks rejected parts. The machine, tended by only one operative, can turn out 100 cylinder blocks a day. Such mechanisms are fundamental to the evolution of automated manufacturing. Exhibit 3-2 shows the close relationship and the progression from manual methods, through mechanization, into the area of automation. There is evident a steady upgrading of unskilled to skilled labor and a redistribution of labor skills as production operations are elevated from the manual area into the sphere of mechanization and automation. Exhibit 3-3 shows graphically how, even in the Ford Motor Company's highly automated line for finishing engine blocks at its Cleveland Plant No. 2, eight levels of mechanization-automation are employed. Even in this epitome of automation, practically all the inspection and assembly operations continue to be performed in a manual rather than an automatic fashion.

The term *automation* has received considerable attention since its introduction in the late 1940s by a Ford Motor Company's vice-president of manufacturing, who coined it as a contraction of the phrase "automatic material motion." Yet automatic plants are not a novelty in industry. As early as 1784 Oliver Evans built an almost completely automatic flour mill on the banks of the Red Clay Creek in Delaware. Evans used water-powered conveyors to move the grain from the storage bins through the milling operations, and thence to the flour-packaging section.

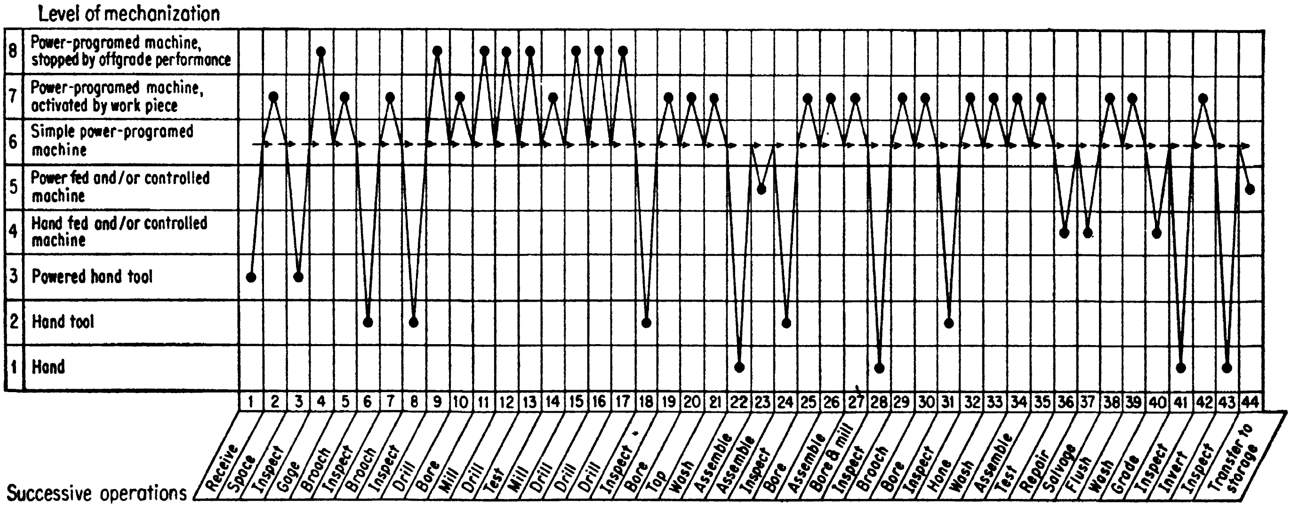
The French weaver Joseph Marie Jacquard is also generally accepted as a pioneer in automation. His loom was operated automatically by a continuous flow of punched cards which "instructed" the machine in the weaving of the desired pattern. The basic principle of this automatic control is best illustrated in a later adaptation, the old-fashioned player piano, in which a series of holes punched on the roll

Exhibit 3-2. Progressive Steps to Automation



SOURCE: *Apparatus Sales Promoter,* General Electric Company, December, 1954, p. 5.

Exhibit 3-3. Levels of Mechanization



SOURCE: Herbert Solow, "Automation: News behind the Noise," *Fortune,* April, 1956, p. 151.

determined what keys were to be played. In the automatic loom devised by Jacquard, the series of holes regulated the selection of the proper threads so that intricate patterns could be woven continuously from the same set of punched cards. There is ample evidence that Jacquard's loom, in use since early in the nineteenth century, was the forerunner of the punched-card system now so widely employed in a great variety of record-keeping and production techniques. The continuous-process industries, such as sugar refining, chemical processing, petroleum refining, and the like, had practiced automation long before the current popularizing of the term. However, it is the application of the continuous-process principle to fabrication and assembly which has captured the imagination of present-day commentators.

It is evident that by their very nature many operations do not lend themselves to automation. This is particularly true when the demand for the product is weak or fluctuates widely. In most such cases the capital outlay needed for the complex mechanisms would not be warranted. Automation, likewise, is generally impossible when the product is in its developmental stage or where the style factor necessitates frequent changes.

Where practical, automation offers significant advantages in better scheduling, more efficient materials handling, better quality control, lower inventories, safer working conditions, upgrading of jobs, and a considerable saving in labor costs. Probably the greatest saving in labor cost is in the reduced manual handling of materials. It is estimated that from one-fourth to one-third of our manufacturing labor payroll is spent simply to move materials and products. About 75 per cent of this materials handling is still done manually. Although lumped indiscriminately into the indirect-labor category, much of this materials movement is an integral part of production. Even in the direct-labor classification, many jobs involve high percentages of materials-handling time, which is traditionally assumed to be part of that job. Automation promises to provide some measure of relief from the mounting costs of materials handling.

The economic obstacles to automation are identical with the deterrents to mechanization. High investment costs, the danger of rapid obsolescence, the increased probability of breakdowns and bottlenecks arising from the very complexity of the machinery, and the loss of flexibility are the most obvious limitations. In many cases the frequency of styling or engineering change makes automation an impossibility. For example, a spokesman for Republic Aviation pointed out that in the development of the F-84 plane, the company built between 4,000 and 5,000 units and averaged 315 engineering changes per week.

Closely related to automation is the new field of cybernetics, popularized by Massachusetts Institute of Technology's Professor Norbert Weiner. In brief, cybernetics pertains to the attempt at evolving a theory of communication and control relating the operation of automatic devices to the automatic functioning of the human body's nervous system.

Also associated with automation are the electromechanical "thinking" machines such as Harvard University's Mark IV and the International Business Machine Corporation's 700 Series of Computers. Obviously, these mechanisms calculate and conclude only when the operative supplies the information and the criteria. Thus these electronic wonders are minus imagination, volition, and purposefulness and are at best an aid to and not a substitute for the human brain. The basic component in all the so-called thinking machines is the high-speed automatic computer. This type of mechanism was envisaged by Charles Babbage, the noted Cambridge mathematician, at the turn of the last century. However, his "analytical engine," worked by intricate wheels and levers, was beyond the mechanical-engineering ability of the time. Despite the allocation of large sums of money to Babbage by the British Government for the construction of the computer, Babbage died before the project could be completed. The first practical adding machine, invented by William S. Burroughs, was introduced in 1885, and the punch-card machine, invented by Herman Holebrith, made its appearance in 1887. The latter, although used by the U.S. Census Bureau as early as 1890, did not make noticeable strides until the exigencies of World War II spurred its large-scale application. Today more than 60 firms are engaged in computer manufacturing.

The remarkable adaptability of these high-speed computers in fields such as insurance, banking, and stock brokerage has resulted in a tremendous upsurge in the productivity of the office worker. Examples such as The Federal Reserve Bank of New York's proof department, consisting of 800 employees and 200 IBM proof machines, handling 1,750,000 checks a day ($2\frac{1}{2}$ times the volume possible on manual sorting systems) are typical. Nevertheless, there are some limitations. The high cost and high work volume requisite limit the application of these machines to large-scale endeavor. The high obsolescence factor is a deterrent to purchase of the equipment, putting a premium upon rental. The excessive heat generated by the larger machines likewise presents problems. A single IBM 650 computer generates enough heat in a single day to heat an average home for a year. Despite these limitations, the automatic computers are steadily finding more uses and more users.

Regardless of how automation is viewed: (1) as a closed-loop or self-correcting system of controls focused on the basic concept of feedback, (2) as complex instrumentation control, (3) as electromechanical data processing, or (4) as the ultimate in progressive mechanization, there can be very little doubt that this is one of the greatest technological advances. Its impact is yet to be fully felt, not only in the areas of production and economics, but also in the social, political, and educational spheres.

COROLLARY 4. Research

Technological change is closely correlated with inventiveness—the creative faculty of contriving new and better means to accomplish more ambitious objectives. Inventiveness, in turn, arises out of a state of mind, characterized by inquisitiveness and an attitude which welcomes change. The broad area of research is generally divided into the fundamental and the applied categories. Fundamental research has been termed the fountainhead of science, the wellspring from which technology is energized. It consists in thinking and experimenting prompted by curiosity and aimed primarily at the extension of the boundaries of human knowledge. Contemplation by the individual is basic and mandatory to fundamental research.

However, great discoveries, such as Newton's law of gravity and Mendel's law of heredity, acquired usefulness only when they were applied to concrete situations. Thus it is applied research which proves the worthwhileness of basic research. Generally, the public is more conscious of the applied research ventures since it is through these that the immediate benefits are realized. Yet without dynamic fundamental research, utilitarian applied research would gradually atrophy. The relative weights currently attached to basic and to applied research in the United States can be inferred from the size of the funds allocated to each area. In 1957, out of a total annual expenditure of approximately 10 billion, less than 10 per cent was allocated to fundamental research. In the government programs, only 7 per cent of the research investment goes into basic research. This disparity in size of funds might be explained in part by the expensive machinery and the large numbers of technicians needed to put a theoretical concept into demonstrable form. Also, these figures are at best estimates, since there is no clearly set line of demarcation between the two categories.

The development of an idea into a useful invention generally passes through the following phases:

1. Speculation Stage. At this point the soundness of an idea depends

entirely upon the genius of its originator and his ability to translate his thoughts into meaningful terms.

2. *Specification Stage.* Once an idea has been "blueprinted," it can more readily be evaluated both by its author and by other technicians.

3. *Sample-structure Stage.* A working model is the best medium to demonstrate the practicability of an idea and also to detect any inherent "bugs."

4. *Service Stage.* During this period the idea is put to commercial use. If the inventor has taken the proper precautions and has secured a patent, he has exclusive right to the use of the invention and to all royalties which might accrue from licensing agreements.

5. *Simulation Stage.* When competitors observe an idea with merit, they invariably attempt to duplicate or imitate. If there is no patent protection, outright pirating of the invention can occur immediately. Otherwise competitors must content themselves with making imitations.

6. *Saturation Stage.* Invariably there comes a time when the public tires of the idea and seeks new interests. In a dynamic situation this change is hastened by technological improvements prompted by research.

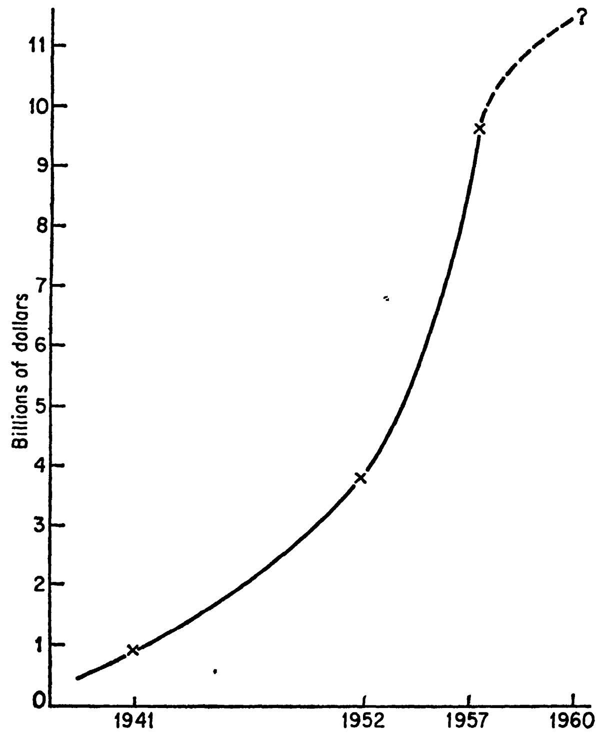
Through this cycle, ideas which at first are sometimes scarcely removed from fantasy gradually assume tangible form, prove their practicability, and are then applied in the rendering of services. Their success invariably stimulates the generation of new ideas, one or more of which ultimately replace the original.

There has been a tremendous upsurge in both fundamental and applied research in this country during the past twenty years. Spending in the United States for organized research and development climbed from $175 million in 1935 to about $10 billion in 1957. In particular, the role of our government in financing research by industry and universities should be noted. The recognition by government leaders of the importance of research to national defense and development has led to the establishment of special governmental agencies for the stimulation of research. Outstanding among these agencies is the Office of Naval Research, created by Congress in 1946. Although the head of ONR reports directly to the Secretary of the Navy and expediency dictates that many of its projects be restricted to naval problems, this agency has an admirable record for the caliber of its work and the freedom it permits its scientists. In 1955, with an appropriation of $60 million, it had about 360 projects under investigation. In addition to its staff of 4,500, ONR also used the facilities and scientists of approximately 217 universities and laboratories.

Another leading research institution maintained by the Federal government is the National Science Foundation, created by Congress in 1950. This agency is dedicated primarily to basic research. During 1954 it disbursed $4 million in 375 grants for basic research in the natural sciences and in the support of 750 talented students in graduate and postdoctoral study.

The research pioneers among American corporations were American Telephone and Telegraph Company and General Electric Company.

Exhibit 3-4. Research Expenditures in the United States



The American Telephone and Telegraph Bell Laboratory was set up before the turn of the century, while General Electric founded a laboratory for applied research in 1900. Both companies have continued their deep interest in pioneering research. Hundreds of other forward-looking concerns, particularly in the electrical-equipment and chemical industries, have also made notable contributions. The degree to which different industries support research is indicated in Exhibits 3-5 and 3-6.

Exhibit 3-5. Research Expenditures and Rate of Return in the United States by Industries

	Research expenditure as a percentage of sales	Return as a percentage of net worth	
	1951	1951	1952
Electrical machinery	6.4	14.5	13.7
Professional, scientific, and controlling instruments	6.4	13.2	11.6
Photographic equipment and supplies	4.8		
Chemical and allied products	2.5	13.2	10.9
Machinery (except electrical)	1.5	13.0	11.3
Stone, clay, and glass products	1.3	19.2	11.7
Motor vehicles and parts	1.2	14.3	13.9
Fabricated metal products	0.9	13.9	10.1
Textile-mill products and apparel	0.9	8.2	4.2
Transportation equipment (except motor vehicle)	0.9	10.0	12.5
Petroleum refining	0.6	15.2	13.3
Primary metal industries	0.4	12.5	9.5
Food and kindred products	0.3	8.1	7.6

SOURCE: *Quality Control and Research,* Scientific Apparatus Makers' Association, Chicago, p. 12.

Exhibit 3-6. Research Expenditures

	(Millions of dollars)		
	1956	1957	Planned 1960
Primary metals	$ 97.9	$ 109.6	$ 145.8
Machinery	506.2	577.1	704.1
Electrical equipment	1,148.9	1,309.7	1,637.1
Aircraft and parts	1,557.8	2,274.4	3,161.4
Fabricated metal products and ordnance	165.2	173.5	209.9
Professional and scientific instruments	252.1	300.0	453.0
Chemicals and allied products	497.8	527.7	617.4
Paper and allied products	42.8	47.9	57.5
Rubber products	73.1	81.9	95.0
Stone, clay, and glass	58.5	66.1	80.6
Petroleum products	204.8	225.3	277.1
Food and kindred products	76.0	85.1	96.2
Textile mill products and apparel	33.8	36.5	42.3
Other manufacturing	1,071.2	1,156.9	1,272.6
All manufacturing	$5,786.1	$6,971.7	$8,850.0
Nonmanufacturing industries	310.4	347.1	418.8
All industries	$6,096.5	$7,318.8	$9,268.8

SOURCE: *Business Week,* Apr. 27, 1957, p. 43.

COROLLARY 5. The Patent System

The greatest inducement to inventiveness and the public disclosure of new inventions is the assurance given by the Federal government that the inventor can secure the exclusive right to exploit his discovery for a specified period of time. This protection, given to anyone who has discovered or invented "a new and useful art, machine, manufacture, or composition of matter or a new and useful improvement thereof" stems from Article 1, Section 8, Clause 8 of the Constitution, which provides that "The Congress shall have the power . . . to promote the progress of science and useful arts by securing for limited times to authors and inventors the exclusive rights to their respective writings and discoveries." Thus a patent is an official document. Under the present law it grants the inventor the exclusive right to his invention for seventeen years.

When a person receives a patent he discloses his idea to the public since the Patent Office makes copies available to anyone for a fee of 25 cents each. This dissemination of ideas is a powerful stimulant to progress, the best alternative to the short-sighted practice of concealing ideas from the public through trade secrets. The passing of the patent into public domain at the expiration of the seventeen-year period releases a fund of knowledge which can be of tremendous benefit to society since anyone can then use the idea as a basis upon which to develop still better ideas.

Although the patent gives an exclusive right of use to the inventor, the government has the power to take over the patent during war or any other emergency by right of public domain. The patent holder can also voluntarily abridge his exclusive rights by licensing others to use the patent. Such licensing agreements can stipulate the royalty rate, the quantities of product to be produced, territorial limitations, and selling prices. In certain instances where it is mutually beneficial, two or more patent holders can exchange their rights by cross licensing.

It should be pointed out that despite the monopolistic character of patents, there are antitrust laws preventing the abuse of patent rights in restraint of trade. The use of patents for purposes of allocating or controlling production, prices, and sales territories and thereby restraining the free flow of commerce by means of domestic or international cartels is illegal. Cartels are actually the antithesis of patent licensing.

There is a popular impression that some of our larger corporations frequently engage in cartel-like practices by suppressing patented inventions. Although these allegations are frequently made, not a single

such charge has ever been substantiated by investigation. Many reliable witnesses, including Thomas A. Edison and three commissioners of patents, have testified at congressional hearings that they have never found an authenticated case of patent suppression. Most such charges are the product of rumors started by irresponsible individuals. Frequently, it is simply not feasible to exploit the commercial potential of an invention. Lack of requisite capital, no immediate market, or the existence of a cheaper and better technology can seriously limit the practical value of a patented invention.

Exhibit 3-7. Ten Leading Patent Recipients, 1940–1957 *

General Electric Company	10,757
American Telephone and Telegraph Company	8,539
Radio Corporation of America	7,894
Westinghouse Electric Corporation	7,567
E. I. du Pont de Nemours and Company	6,338
Esso Standard Oil Company	4,899
General Motors Corporation	4,041
Eastman Kodak Company	3,784
Bendix Aviation Corporation	3,113
American Cyanamid Company	2,872

* The patents granted to these companies during this period equal 12 per cent of all patents issued.

SOURCE: *Business Week*, Jan. 26, 1957, p. 149.

Another supposed abuse of the patent system is the practice of stretching the seventeen-year time limitation by use of the patent-pending device. On the average, it takes three years and seven months for the Patent Office to pass on the acceptability of an inventor's petition. This lag is accentuated by the technical complexity of patent processing and the lack of adequate personnel. This has resulted in a backlog of nearly 200,000 applications. The time lag can, by legal machination, be extended for even longer periods. Thus George Selden's application for a patent on the internal-combustion engine, filed in 1879, was not granted, because of deliberate delays by Selden, until 1895.

The patent system has been termed the independent inventor's traditional incentive system. Its effectiveness is evident in the approximately 80,000 applications received annually by the Patent Office, about half of which are eventually approved. Since the creation of the Patent Office in 1790, nearly 3 million patents have been granted. Although there was a decrease in the rate of patent applications per 1,000 citizens, from 0.77 in 1920 to 0.46 in 1955, there seems as yet to

be no dearth of inventiveness. A number of factors have tended to reduce the rate of patent applications. The basic fee charged by the Patent Office is only $60, but the mounting costs of legal assistance provided by patent attorneys, both for the patent petition and for protection against infringement, serve to dampen the enthusiasm of many would-be inventors.

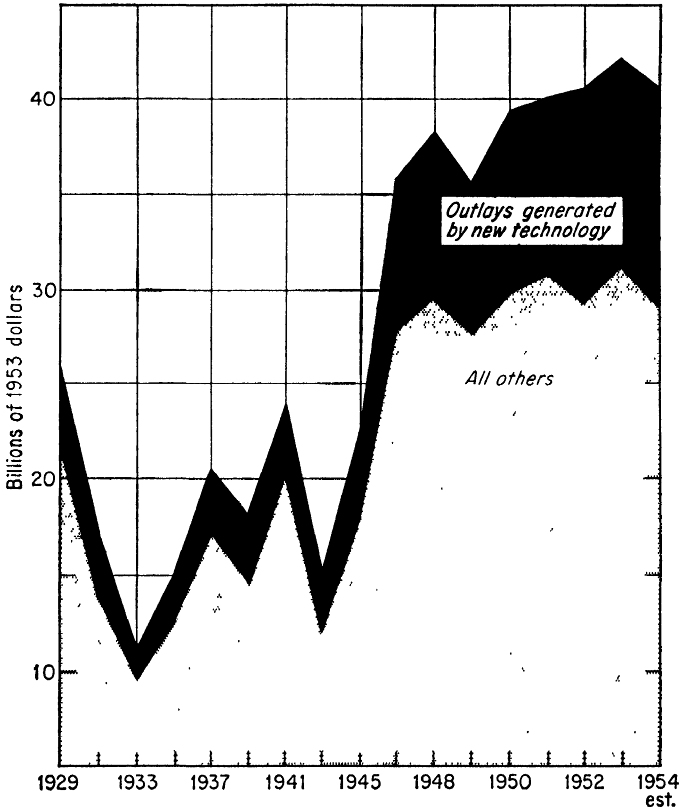
Because of the tremendous strides being made in science and engineering, it is becoming progressively more difficult for individuals without highly specialized training to conceive new ideas. There is very little opportunity in the modern technology for the old-style gadgeteer to stumble upon a major invention. Then too, the modern inventor generally needs complex and costly equipment to put his ideas into practice. Finally, there is no absolute assurance given by the Federal government against infringement. Not only must the inventor prove that his idea is "new," he must also initiate action against infringers. In this respect the recent attitude of the Federal courts has been most discouraging to patent holders. For example, the Appeals Court of the Second District, which includes New York City, heard 38 cases involving patents between 1948 and 1953. In 37 instances the court ruled that the patent was either invalid or not infringed. The United States Supreme Court has been almost equally severe. Justice Douglas introduced the "flash-of-genius" test which the majority of the present court apparently upholds. This test provides that a new device, however useful, must reveal the flash of creative genius and not merely the skill of the calling. Justice Black has elaborated by insisting that "the invention, to justify a patent, had to serve the ends of science —to push back the frontiers of chemistry, physics and the like; to make a distinctive contribution to scientific knowledge." Obviously, only a small percentage of all patent applications can meet these stringent criteria. As a consequence of these and other obstacles, there has been a noticeable disinclination on the part of the individual inventor to carry his project beyond the idea stage.

SIGNIFICANCE

Technology has already been referred to as the mighty multiplier of economic goods and services. A fertile technology, producing a steady stream of new inventions and innovations, is the primary requisite for a dynamic economy. This is graphically depicted in Exhibit 3-8, which differentiates the outlays for new plant and equipment in the "new-technology" industries from the expenditures in the older-technology industries over a twenty-five-year period. This new-technology group includes industries manufacturing instruments and con-

trols, electrical machinery, oil-field and mining machinery, materials-handling machines, business machines, and air-conditioning apparatus. These industries have been characterized by both a rapidly advancing technology and increasing consumption of power. In 1929 outlays for new plant and equipment in the new-technology industries totaled $4

Exhibit 3-8. New Plant and Equipment Investment in American Industry



SOURCE: Gilbert Burck and Sanford Parker, "The Mighty Multiplier," *Fortune*, October, 1954, p. 110.

billion, or 18 per cent of United States capital expenditures. In 1947 the total outlay was $7.8 billion, equal to 25 per cent of all capital investment, while by 1954 this group accounted for $11.7 billion, or 33 per cent of such expenditures. The remarkable aspect of this new-technology group is its very rapid growth, three times the rate of all capital spending. In the post–World War II period, four-fifths of all

growth in United States investment in new production facilities has been in this category.

There is no implication in this presentation of statistics that other industries are apathetic to change. Actually, the "all other" classification includes many industries which have made significant strides in the use of better equipment. This illustration does show, however, that American industry can continue its expansion only if new processes and new machines are forthcoming. The close relationship between new technology and higher productivity has been adequately demonstrated. Economists since Adam Smith have stressed this relationship. Even the dire prediction of Thomas Malthus as to the eventual inability of the world to support a geometrically growing population is based upon the premise that "the state of the arts remains constant." It has been the tremendous changes in the state of the arts, or technology, which have delayed the impact of Malthus's prediction. Only a few decades ago Lord John Maynard Keynes, generally assumed to be the outstanding economist of the present era, was guilty of a similar underestimation of technological dynamism.

Economists and historians have tended to view the technological advancement of the past hundred and fifty years as a temporary phenomenon whose decline must surely come about in the near future. For many years the dire prognostications of economists resulted in that field of learning being dubbed "the dismal science." There seems to be no need for an elaborate justification of our current reliance upon technological progress. The errors of short-sighted analysts and irresponsible scaremongers who envision the present technology as a mastery of machines over men are very evident. The significance of technological change, if not already patent, should become more evident in the subsequent chapters dealing with production techniques.

ILLUSTRATION 1. Introduction of Power Equipment[4]

Power machinery was introduced on a large scale in the British cotton industry in 1840. At that time there were approximately 5,000 cotton operatives employed in Manchester, England. With the advent of the new technology, these cotton operatives *knew* that there would now be work for no more than 1,000 operatives. In misguided defense of their jobs, the workers invaded the mills where the new equipment was being installed. They smashed the machinery, beat up the "scabs" who were being taught to operate the power equipment, and burned down the mills. This antipathy toward technological innovation is typ-

[4] Frederick W. Taylor, *The Principles of Scientific Management,* Harper & Brothers, New York, 1947, cf. pp. 44 and 65.

ical of the so-called lump-of-labor theory. The major premise of this theory states that there is a given and inflexible quantity of work to be performed during a specified period of time. If the number of employees is suddenly increased or if machinery is introduced to replace manpower, then the average quantity of work available per worker is proportionately reduced. Thus the Manchester cotton operatives' revolt was, in the light of the lump-of-labor attitude, simply a fight for self-preservation.

The inadequacy of the lump-of-labor theory is clearly evident in the subsequent experience of the cotton industry. Despite the militant reaction of the workers, the machinery was installed in the mills. Between 1840 and 1910 the number of cotton operatives in the Manchester region increased from 5,000 to 265,000. Accompanying this fifty-three-fold rise in employment, there was a gain in the yardage of cotton cloth produced, averaging between 400 and 500 times the former output.

Frederick Taylor commented on this and parallel situations, stating:[5]

> There is hardly any worse crime to my mind than that of deliberately restricting output, of failing to bring the only things into the world which are of real use to the world, the products of men and soil. The world's history shows that just as fast as you bring the good things that are needed by man into the world, man takes and uses them. That one fact, the immense increase in the productivity of man, marks the difference between civilized and uncivilized countries.

QUESTIONS

1. Is there any evidence that the lump-of-labor theory persists even at the present?
2. How is the guaranteed annual wage related to this concept?
3. What validity is there in the contention that workers displaced by technological change will be reabsorbed by the industries making the new machines?
4. Are there any significant economic differences in this example and in the recent mechanization of the bituminous-coal and the cotton-agriculture industries?

ILLUSTRATION 2. Karl Marx on Mechanization

Owing to the extensive use of machinery and to division of labor, the work of the proletarians has lost all individual character, and, consequently, all charm for the workman. He becomes an appendage of the machine, and it is only the most simple, most monotonous, and most easily acquired knack that is required of him. Hence, the cost of production of a workman is restricted almost entirely to the means of subsistence that he requires for his maintenance, and for the propagation of his race. But the price of a commodity, and also of labor, is equal to its cost of production. In pro-

[5] *Ibid.*, p. 25.

portion, therefore, as the repulsiveness of the work increases the wage decreases. Nay more, in proportion as the use of machinery and division of labor increase, in the same proportion the burden of toil increases, whether by prolongation of the working hours, by increase of the work enacted in a given time, or by increased speed of the machinery, and so forth.

Modern industry has converted the little workshop of the patriarchal master into the great factory of the industrial capitalist. Masses of laborers, crowded into factories, are organized like soldiers. As privates of the industrial army they are placed under the command of a perfect hierarchy of officers and sergeants. Not only are they the slaves of the bourgeois class and of the bourgeois state, they are daily and hourly enslaved by the machine, by the foreman, and, above all, by the individual bourgeois manufacturer himself. The more openly this despotism proclaims gain to be its end and aim, the more petty, the more hateful and the more embittering it is.[6]

QUESTIONS

1. What are some examples of occupational downgrading resulting from mechanization?
2. Comment on Marx's premise that "the work of the proletarians has lost all individual character, and, consequently, all charm for the workman."
3. Is there any evidence that, contrary to Marx, mechanization has elevated rather than lowered the level of industrial endeavor?
4. Does Marx use valid norms in evaluating our industrial system?
5. Has the "burden of toil" increased in proportion to the increased use of machinery?
6. Are Marx's views on wage theory sound?

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CHAPTER 4

Concept of Standardization

DEFINITION AND DESCRIPTION

In the generic sense, a standard is any commonly accepted gauge for measuring and comparing physical properties, performance, and mental acts. The nature and function of standards can be inferred from such well-known synonyms as criterion, norm, model, precept, law, measure, and yardstick. The more important characteristics of a standard include acceptance by the group, stability, and comparability. These aspects focus attention upon the use of a standard as a constant factor by means of which related variables, including entities, actions, and even thoughts, can be compared.

The great variety in the number and uses of standards makes categorizing rather difficult. The most basic classification would differentiate between (1) physical standards, (2) performance standards, and (3) philosophical standards.

Physical standards are measures of reality or existence. They pertain to material objects which can be compared as to weight, number, dimension, quality, or value.

Performance standards compare specific actions with commonly accepted beliefs, policies, laws, customs, rituals, habits, and similar intangibles. Conformity or nonconformity of the variable in question to the accepted constant factor is largely dependent upon judgment and value systems. However, since performance implies action and the use of tangible instruments, this type of standard resembles physical stand-

ards in so far as variations can be measured in minute degrees or numbers. Performance standards in industry relate to topics such as operating procedure, company policy, manufacturing practices, safety regulations, personnel relations, and the like.

Philosophical standards pertain to that limitless sphere of speculation where one's thoughts and beliefs are compared with commonly accepted ideals. Religious, psychological, political, sociological, and educational standards are generally in this category. With the evolution of a management profession, there has been a noticeable increase in the application of philosophical standards to industrial administration. However, since the prime purpose of industry continues to be the creation of useful goods and services, it is patent that performance and physical standards will be most in evidence.

If a standard can be defined as any commonly accepted gauge for measuring and comparing physical properties, performance, or mental acts, then standardization is simply the process whereby all pertinent variable items are made to conform as closely as possible to the selected constant factor or standard. The broad subject of standardization is applicable to every basic component of industrial administration including raw materials, product, manpower, equipment, production techniques, and managerial practices and policies. Although there may be various reasons for securing conformity through standardization, the basic purpose for the use of standards in industrial management is to secure and maintain control. As was indicated in the first chapter, the very essence of organization is the control of group activities for the attainment of specific objectives. Standardization facilitates this requisite control. Without some common denominator by which individuals can compare aspirations, actions, and tangible products, group cooperation is impossible. Where standards are imperfect, variable, arbitrarily imposed, devoid of sanction, or not properly understood, organization is inevitably weak.

Permanency of Standards. Standardization and innovation are generally assumed to be antithetical. Innovation implies deviation from an accepted pattern—physical, behavioral, or mental. Obviously, then, unbridled innovation hinders concerted effort and thus impedes organization. On the other hand, as was demonstrated in the previous chapter, which dealt with technological change, civilization and progress are practically synonymous with certain types of innovation. Complete and immutable standardization would result in a stultifying, static state. This dilemma is readily resolved when it becomes evident that new standards are always forthcoming. When an innovation has been

proved to be desirable and is accepted by a group, the innovation becomes a new standard. Thus the terms *standard* and *standardization,* even though they pertain to common denominators which are assumed to remain relatively constant, are not comparable with certain metaphysical concepts, such as being, truth, beauty, etc., which are generally assumed to be immutable. Research in this atomic age has conclusively shown that permanency, at least as far as material objects and the actions of human beings are concerned, simply does not exist.

Standardized Performance. Consistency in performance of repetitive actions is mandatory for effective organization. Lacking this consistency, planning and control are virtually impossible. In very small organizations the requisite uniformity can more readily be maintained since supervision is more immediate and comparisons can easily be made. However, as the scale of enterprise increases, the difficulty in securing the desired uniformity mounts in geometric proportions. A number of management-facilitating techniques have been introduced into the industrial sphere in the past few decades for the express purpose of securing a higher degree of consistency in repetitive tasks. Among the means by which this standardization is accomplished are such varied aids as policy manuals, standard-practice instructions, job descriptions, process charts, specification lists, standard data, operations-analysis manuals, etc.

In every instance the objective is the attainment of more effective control over operations. Additional advantages of standardizing performance include improved supervision, ease in record keeping, facility in making assignments, better adaptability of manpower to specific tasks, and, in summary, a significant reduction in costs. Among the limitations are the high development, installation, and administrative costs when the volume of repetitive actions is relatively low. Then too, standardization in this area is considered by some to be detrimental to initiative and to productive thinking. While it is true that in some instances standardization of performance can degenerate into bureaucratic formalism and thence into organizational apathy, adequate safeguards can usually be set up. The notion that stultification results from standardization has been refuted by many leading management experts. For example, nearly fifty years ago one of the pioneers in modern management, Harrington Emerson, contended that standard instructions do not destroy a man's initiative and make him an automaton. To illustrate this point, Emerson emphasized that compared with a bird sailing through the air or a squirrel scampering down a tree, a staircase does indeed limit a man in his movement

from one floor to the next. Yet despite this regimentation of movement by the staircase, it must be admitted that, lacking such a staircase, there would probably be no significant vertical movement.

There is considerable disagreement among managerial writers in respect to the terminology applicable to the subject of performance standards. Although the following section is not intended to be definitive, it is hoped that a logical relationship can be demonstrated in the pertinent terms. Exhibit 4-1 attempts to differentiate the terms according to:

Exhibit 4-1

	Specific	General
Operational (how to)	Project	Procedure
Organizational (why)	Plan	Policy

1. The extent to which they are specific or general in character
2. Their primary concern with either (*a*) the determination of basic objectives and related functions, or (*b*) the precise manner in which these functions will be carried out

Thus a project generally refers to a very specific assignment, with detailed instructions describing exactly how the given operation is to be carried out. At the opposite extreme is a policy which is usually a very general expression of the basic tenets of the organization. One step further in this latter direction would lead to the concept of management philosophy described in corollary 1, Chapter 2. Although there is some overlapping, the following list proposes a progression of the pertinent terms from the extremely general to the very particular.

Philosophy. A system of thought which explains certain phenomena and prescribes a set of principles for resolving problems related to the attainment of a specific goal.

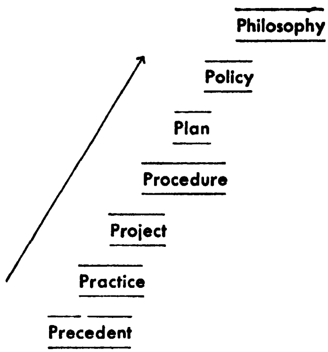
Policy. A general statement as to the action to be taken relative to a basic tenet of the organization's philosophy. Policies serve as broad channels to guide the efforts of the group toward the desired objectives.

Plan. A detailed course of action by means of which policies are activated and implemented. Plans give meaning and realism to the broad, general, and even idealistic organizational policies and philosophy. Plans are sometimes divided into those which are primarily organizational as contrasted with those which are strictly procedural.

Procedure. Procedural plans logically lead to the specific prescriptions for the performance of actions requisite to the attainment of

organizational objectives. The term *system* is frequently used interchangeably with *procedure*. These terms can be differentiated as to degree since a procedure is concerned with the actuating aspects of a system, which in turn refers to the structural arrangement of the required facilities and functions. The term *method* is likewise often considered synonymous with procedure. A differentiation is possible if a procedure is viewed as a composite of all the various actions performed by different individuals and in different stages. A method, on the other hand, is generally more limited, applying to a single designated work cycle and to a specified work place.

Exhibit 4-2. Scalar Progression of Performance Standards



Project. As plans and procedures approach the tangible and the immediate, they assume the refined proportions of specific tasks. A project might be viewed as a series of related groups of tasks which are logically combined to form one step in the pertinent procedure. Projects, in turn, can be subdivided into specific assignments, operational cycles, or tasks.

Practice and Precedent. Technically, these terms should not be included in this listing since they are extraneous to the formal aspects of organization. A practice generally arises out of necessity. When individual members of a group, without specific instructions from supervisors, seek and discover an easier or better way of fulfilling their obligations, they invariably develop a routine in operation termed a practice. A precedent differs from a practice only in the degree of repetitiveness. A precedent once established and frequently followed becomes a practice. Thus in a process similar to that by which common law developed, standards of performance evolve from precedent into practice, and eventually into organization philosophy.

Benefits of Standardization. In general, the advantages of standardization are identical with the advantages of division of labor. Textbooks dealing with this topic generally set forth rather lengthy listings of the benefits accruing from standardization. For example, Professor Moore[1] gives a very detailed listing of 84 such benefits. The following list, although somewhat briefer than the typical listing, focuses attention upon the major positive returns from standardization:

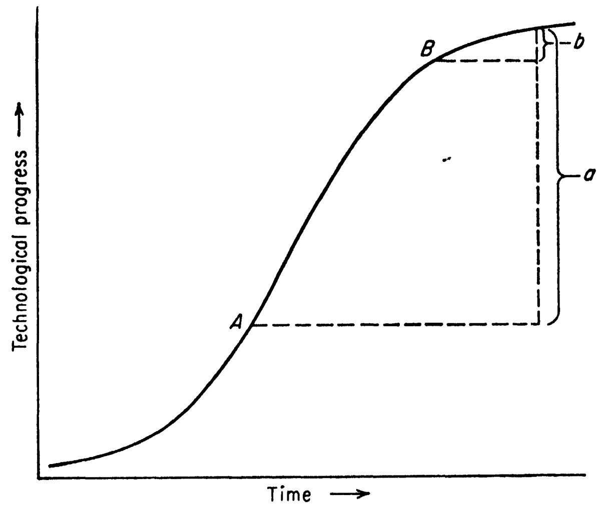
1. Financial benefits
   a. Lower unit costs
   b. Increased probability of profit
   c. Reduced capital requirements
2. Production benefits
   a. Better utilization of facilities
   b. Better quality of product
   c. Improved inventory control
   d. Work stabilization
   e. Reduced labor requirements
3. Marketing benefits
   a. Elimination of marginal lines
   b. Decreased handling and storage costs
   c. Better servicing
   d. More effective advertising
   e. A guaranteed grade of product
   f. A better buy

When to Standardize. Proper timing is of paramount importance to the successful introduction and application of standards. In this connection, adequate attention must be given to the prevailing level of technology and to the prospects for immediate advances in the technological level. A premature setting of rigid standards can have a strait-jacket effect. This can be particularly disastrous in a highly competitive situation where the competitors have not standardized their products or processes and therefore have more flexibility in adapting to technological improvements. Obsolescence, the outmoding of goods, equipment, or processes for technological, economic, or psychological reasons, is the penalty paid for premature standardization. The theory underlying the proper timing of standard setting is depicted in Exhibit 4-3. The two equilibrating forces, the horizontal pull of time and the

[1] Leo B. Moore, "Industrial Standardization," in W. G. Ireson and E. L. Grant (eds.), *Handbook of Industrial Engineering and Management*, Prentice-Hall, Inc., Englewood Cliffs, N.J., 1955, pp. 631–633.

vertical pull of technological progress, determine when standards should be set. The optimum point for standardization is reached when the upward pull of technological progress is minimal. In other words, it is desirable to standardize when no significant changes in a particular technology are anticipated within the foreseeable future. The logic is apparent in Exhibit 4-3 in the relative lengths of lines *a* and *b*.

Exhibit 4-3. Time–Technological-progress Curve



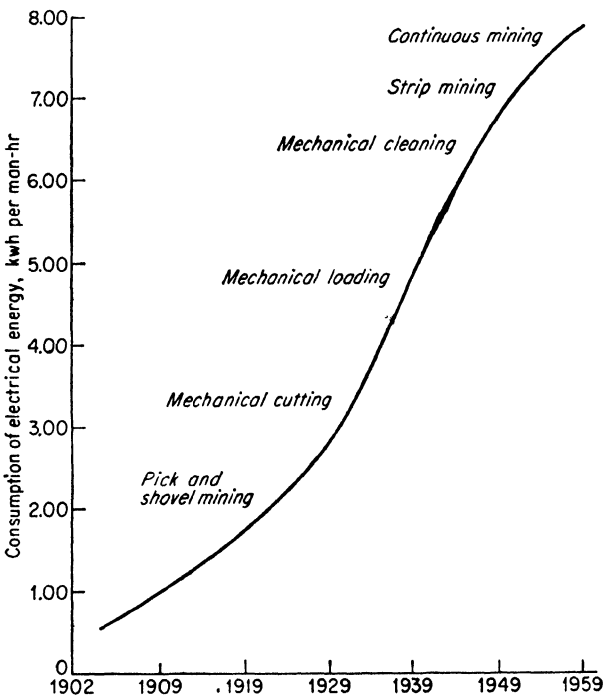
These indicate the technological lag for manufacturers *A* and *B*, who standardized their products at different times. Manufacturer *A* obviously was too hasty in adopting standardization in comparison with manufacturer *B*.

The timing of standard setting is further complicated by the fact that the technological-progress curve almost never has the perfect symmetry shown in the illustration. Instead, technological progress would be more realistically expressed if the curve proceeded upward in many short, sharp climbs which rapidly taper off into much longer horizontal extensions. These plateaus indicate a temporary lull in technological progress.

A further obstacle to determining the proper time to standardize is the difficulty in selecting a suitable gauge of technological improvement. For example, the degree of electrification is an excellent measure of progress within an industry. Exhibit 4-4 shows the application of this criterion in measuring technological progress in the bituminous-

coal industry since 1902. During this period there were a number of advances in mining techniques. The approximate times of introduction of five major technological changes are indicated in the chart. It should be apparent from the steady upward climb of the technological-progress curve that this measure is a composite, influenced by all the methods and mechanisms employed in American bituminous-coal mining. An individual mining operator wishing to determine when it

Exhibit 4-4. Technological Progress in Bituminous Coal Mining



SOURCE: Stanley Vance, *A Critical Analysis of the Data and Techniques Available for Technical Capital Measurement in Bituminous Coal Mining,* University of Pennsylvania Press, Philadelphia, 1951, p. 179.

might be judicious to standardize a particular mechanism, as, for example, a loading machine, would need much more information relative to the technological changes in a specific mechanism or process. With this information he could then exercise judgment as to the feasibility of embarking on a program of standardization in one definite area. Unfortunately, the specific data requisite for such decision making are rarely available when needed.

DEVELOPMENT

Development of Physical Standards. Although the basic concept of standardization can be traced back through antiquity, the widespread application of the concept to industrial management is a relatively recent phenomenon. There are some outstanding examples of the use of relatively rigid standards of measurement in the ancient world. The Great Pyramid of Giza was so constructed that it measured 500 cubits on each side. At 18.24 inches per cubit, the perimeter totaled 3,040 feet, which is exactly one-half of the value of a meridian mile, that is, one-sixteenth of a degree of the earth's meridian. Such precision in measurement by the ancients is remarkable considering that science and scientific instruments were in a most primitive state. Another example of the rigidity associated with the establishment of physical standards is provided by the early sixteenth-century contribution, in England, to our modern system of measurement of length. This measure, the inch, was derived by this process:

12 hairbreadths = 1 poppy seed
4 poppy seeds = 1 barley corn
3 barley corns, end to end = 1 inch

It is interesting to note that every major civilization, and in fact every important nation, has attempted, during its heyday, to introduce uniform codes of action and standard units of measurement. The vigor with which these standards were promulgated and enforced was almost invariably a measure of that nation's or that society's vitality. Disintegration of political and social order has practically always been marked by a decline in universal standards and a multiplication of regional and local measures.

The two major systems of weights and measures currently in use are the English, or imperial, system and the metric system. The latter is basically decimal in character, while the former is a fractional system. The industrial limitations of the fractional method became apparent as soon as craftsmen began to apply precision in measurement and particularly when products and component parts were to be duplicated. Machinists can work with facility in fractions of an inch up to the sixty-fourth, but beyond that point fractions are unwieldy. In current practice refined measurement divides the inch decimally into hundredths, thousandths, and even millionths of an inch.

The metric system is actually the product of universal dissatisfaction with the multiplicity of inexact units of measurement prevalent in the eighteenth century. For example, in France alone there were

391 different local units of weight, while a foot could refer to one of 282 different units of length. In the United States, during the postrevolutionary period, a bushel of oats varied anywhere from 28 to 38 pounds, depending upon the locality.

This confusion in the use of standards is not a characteristic confined exclusively to bygone eras. Jawaharlal Nehru's many ambitious programs for modern India include a hoped-for standardization in weights and measures, in the coinage system and in the calendar. Currently more than 140 different systems of weights and measures and 30 different calendars are used in India. In 1957 Nehru established a national calendar of twelve months comparable to the Gregorian, inaugurated a new decimal coinage, and suggested a uniform metric system for weights and measures.

The first successful attempt at devising a universal weights-and-measures system was made during the French Revolution. Prince Talleyrand visualized a unity in weights and measures as one avenue toward French national unity. Talleyrand delegated to the Royal Academy of Science, among whose membership were the eminent mathematician Marquis de Laplace and the renowned chemist A. L. Lavoisier, the task of devising a new system based on the principles set forth by James Watt twenty-odd years earlier. Watt's concept was founded upon a fundamental standard of length based on the earth's dimensions. All components of the system were to be decimal ratios and multiples of the basic standard. The meter, which was finally accepted as the standard, is generally assumed to be one ten-millionth part of a quadrant of the earth's meridian extending between specified points north and south of the 45th parallel.

Since its introduction more than 150 years ago, the metric system has become a universal standard except in British and American territories. Several serious attempts were made to have the system adopted officially by the United States. Every such proposal has, however, ended in inconclusive deliberation.

Although the Constitution gives Congress the right to set units of weights and measures, no serious attempt at regulation was made prior to 1901. In that year Congress established the National Bureau of Standards. Exigency was the basis for this action. By the turn of the twentieth century the rapid expansion of business and industry necessitated the formulation of a common language of measurement. By this time it became apparent that there was an imperative need not only for standards of simple measurement but also for standards of precise determination of physical constants. Values had to be set and rigidly maintained, for example, for units pertaining to temperature,

humidity, viscosity, luminosity, radiation, frequency, etc. Since 1901 the Bureau of Standards has assumed the function of acting as custodian of basic standards. In addition, it serves as research agent in determining physical constants and the properties of materials.

The establishment of the Bureau was preceded in 1898 by the organization of the American Society for Testing Materials, the first such national technical society. Its objectives were, and are, the promotion of knowledge relative to the raw materials of industry and the standardization of specifications and methods of testing. The membership of this group presently numbers between 7,000 and 8,000 producers, consumers, scientists, and engineers. Out of its numerous research projects and the work of its special committees, the ASTM has developed nearly 2,000 standards applicable to and accepted by industry.

Another equally important national organization is the American Standards Association, organized in 1908. This group, although it does not initiate standards, stimulates interest in the adoption of commercial and industrial standards on a nationwide basis.

In addition to these two major organizations, there are numerous special-interest groups which are industry-sponsored. This initiative by industry has been deemed mandatory since the National Bureau of Standards initially dedicated its energy almost exclusively to the scientific aspects of standards. Commercial and industrial standardization, that is, the process of setting standards of style, convenience, or policy, was assumed to be a matter for trade rather than scientific agencies. Although this attitude was modified considerably in the 1920s, after Herbert Hoover became Secretary of Commerce and directed the Bureau to set up new divisions to promote the adoption of commercial standards and of simplified practice, industry-sponsored agencies continue to take an active role in promoting industrial standardization.

At present approximately forty countries have established national standardization agencies. Since the Metric Convention, held in 1875, there have been numerous attempts at securing international agreement on scientific nomenclature and measurement units. Out of such cooperation there has developed an International Organization for Standardization whose first general assembly, held in Zurich, Switzerland, was attended by delegates from twenty-six member nations.

Out of this rather sketchy description of the evolution of industrial standards, first in the measuring of length, capacity, and time, and later in the determination of a great variety of scientific constants, the following should be obvious:

1. Industrial standardization is distinctly a twentieth-century phenomenon.

2. New industrial and scientific standards are steadily being devised as exigency or expediency dictate.

3. Universal acceptance of the new improved standards is indicative of organizational vitality.

4. Effective organization and control cannot be achieved without voluntary acceptance of the selected standards by the members of the organization.

COROLLARY 1. Division of Labor and Related Concepts

The modern industrial system could never have become a reality without the economic and social acceptance of the concept of division of labor. The basic concept itself is probably as old as man's first organizational endeavor. The logic underlying the need for division of labor is evident in Plato's statement that "More is done and better when one man does one thing according to his capacity and at the right moment." There is ample evidence that in every ancient society laborious tasks were allocated to specific individuals on some predetermined and acceptable basis. An excellent example of this apportionment of necessary labors was provided by the American pioneer family, which tended to carry out most production functions in an autonomous fashion. As a rule each family produced its own food, clothing, tools, and shelter. More important for our purposes, each member of the family had specific chores to fulfill in providing these necessities. Much of the division of labor, as was practiced by the pioneers, did not require a high measure of skill. Consequently, substitution by one family member for another in the performance of these duties was quite commonplace. However, as these chores began to require greater proficiency, their performance became more and more the province of the individual possessing the requisite skills.

Specialization by Trades. Out of such division of labor came specialization by occupations or trades. This specialization was greatly accelerated by the growth in the size of markets. Similar wants tended to multiply so that there was enough of one type of work to warrant concentration of a man's time and effort on one trade. The historical sections of the previous chapters indicate that such specialization was accepted and practiced rather extensively by practically all ancient civilizations. In the Homeric age, for example, the four basic trades—*tekton, chalkeus, skytotomos,* and *kerameus*—were distinguished by the materials used—wood, metal, leather, and clay.

Specialization by occupations or trades means that the work to be

performed is divided into a number of homogeneous and distinct economic activities, each associated with a specific process and with an identifiable service or a finished or semifinished product. This form of specialization usually implies that the tradesman himself, or a closely supervised apprentice, carries out all the operations necessary for completion and distribution of the product or service. Invariably there is an intimate association of tradesmen with service and product which is conducive to quality performance and to a pride in workmanship. The guild system of medieval times was an excellent example of a highly developed society based on an extensive application of specialization by trades.

Specialization by Function. In the evolutionary development, the next phase might be termed specialization by function. Initially this involved the separation of such basic economic functions as raw-material preparation and procurement, fabrication, transportation, wholesaling, retailing, and financing. In other words, the lengthy production-distribution cycle was divided into relatively short and distinct activities, with specialists performing the specific phases. The tremendous growth in scale of enterprise and the increasing complexity within each function have led to considerable refinement. Thus, for example, the personnel-administration function has become an accepted adjunct of modern industrial enterprise. In turn, this function itself has been subdivided into a score or more subfunctions easily identifiable by such titles as recruitment, training, employee relations, job analysis, etc. In recent years the widespread application of specialization by function in managerial activities has even led to rather significant modifications in the predominant type of industrial organization structure.

Specialization by Tasks. Specialization by tasks is a still further refinement wherein related activities encompassed within a trade or function are segregated and designated as specific work assignments. This type of specialization might be differentiated in so far as it relates to routinized performance of a relatively short work cycle. The routine character of the work and its repetitiveness provide a facility for the workman in acquiring technical competency, with resultant improved performance. It was largely the universal adoption of this form of specialization by industry that made possible the modern manufacturing system.

Specialization by Operating Cycle. This was, and is, particularly the case where the routine aspects permitted a further development, namely, specialization by operating cycle. In this instance a transfer of skill from the workman to the tool becomes not only physically pos-

sible but also economically feasible. Mechanization, then, logically follows this division of work into relatively short and frequently repeated operating cycles.

Specialization by Elemental Motion. Specialization by elemental motions, or by therbligs, would be the logical culmination of the division-of-labor concept if it were practiced in the extreme. Therbligs (a modification of the name Gilbreth spelled backwards) can be defined as the fundamental elements of motion or mental process through which the different parts of a human body proceed in the performance of work. These elements include basic motions such as searching, selecting, grasping, holding, etc. The nature and function of these fundamental elements of motion will be more thoroughly discussed in the chapter on work simplification. At this point, mention has been made of therbligs merely to indicate the ultimate in the intensive application of the concept of division of labor.

From this presentation it should be evident that the basic idea of division of labor stresses the importance of:

1. Dividing complex operations into components which are less complex and therefore more readily mastered.

2. Increasing the incidence of the particular activity so that it becomes economically feasible for individuals to dedicate attention and effort to a mastery of the specific actions.

3. Reducing the onerous aspects of labor. This can be effected when the operation becomes sufficiently repetitive so that the skills of the workman can be transferred to a mechanism.

4. Adequate attention must be given to both the economic and the psychological considerations attendant on the application of the preceding concept.

The most frequently mentioned advantages of division of labor, as will be explained in illustration 1, are:

1. An increase in the workman's dexterity, made possible by the reduction in the number of different operations expected of him.

2. A significant saving in time normally lost in the movement from one type of work to the next.

3. A stimulus to invention and to the introduction of machines, which multiply the productivity of manpower.

4. A balanced cycle of operations, which makes possible the utilization of lower grades of labor in the cooperative performance of complex tasks.

The more obvious negative aspects of specialization include:

1. An inordinate reliance of the individual upon the system. Occa-

sional malfunctioning of the system, as in a depression, clearly demonstrates this imperfection.

2. A tendency to routinize to the point where individual incentive and pride of accomplishment can be impaired.

3. Difficulty in movement from one specialized area to another.

Division of labor has been included as a corollary of standardization because the two concepts are inseparable. Standardization can be effected only when laborious tasks are subdivided to the point where they can be routinized. The increased incidence of a homogeneous type of endeavor makes it feasible to begin the process of determining standards. Thus division of labor is a prerequisite without which industrial standardization could never have developed.

COROLLARY 2. Simplification

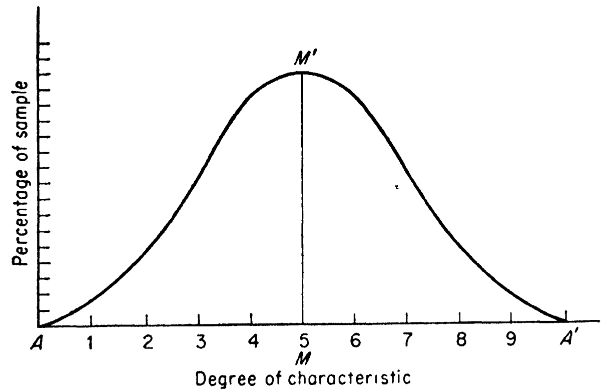
Standardization and simplification are sometimes assumed to be synonymous. Although they are manifestations of the same industrial activity, there is a distinction between these terms. Standardization has been defined as the process by which all pertinent variable items are made to conform as closely as possible to a selected constant factor. Simplification is the process by which nonessential differences in products, processes, and equipment are eliminated. The objective of such simplification is the attainment of the optimum in the number of available varieties. Thus, although the term could be applied to physical characteristics, performance attributes, and even to thoughts and beliefs, it is generally restricted in industrial usage to reduction in variety in products and processes. As a rule, simplification is an adjunct of and a prerequisite for standardization.

A simple example from basic statistics might help clarify the distinction between standardization and simplification. Frequency distribution is very often represented by the normal curve or one of its many variants. The normal curve, depicted in Exhibit 4-5, shows (1) the number or percentage of the items possessing the characteristic being studied (vertical scale) and (2) the varying degree of that characteristic (horizontal scale). In the hypothetically perfect distribution, the line *MM′* would represent the point where exactly half of the items would have values greater than *MM′* and half would have values less than *MM′*. Although some of the items deviate to the extremities, most tend to be concentrated within the area adjacent to the line *MM′*. This phenomenon is known as central tendency and is measured by such familiar norms as the arithmetic mean, the median, and the mode. If rigid standardization were to be applied, all items within the scale

AA′ would be made to conform to the value of the central point *MM′*. Simplification, however, would not necessarily entail so drastic a reduction in variations. Simplification might proceed from either or both extremities, *A* and *A′*, and consist in the elimination of only a few of the furthest-removed deviations. Consequently, simplification and standardization, although intimately related, cannot be used interchangeably.

Heterogeneity in products and processes complicates the industrial manager's function of making decisions. An increased incidence in variables frequently necessitates the consideration of additional alternatives. Even where the choice is between two or only a few alternatives, variety compounds the difficulty in making a judgment as to relative worth. Thus a reduction in variance through judicious application of simplification techniques should facilitate the decision maker in the process of selection.

Exhibit 4-5. A Normal Curve



The basic problem in simplifying an existing situation is to determine what is essential and what is superfluous. In the sphere of industry this frequently leads to a dilemma, involving the marketing, production, and engineering divisions. The marketing personnel are primarily concerned with the form of the product, its aesthetic appeal, its usefulness, and particularly its salability. The production section's interest is in the fabrication of the product. Availability of production facilities and cost considerations are paramount. The engineer's concern is with the product's function, the measure of utility it will provide.

By far the greatest pressure to resist simplification comes from the marketing personnel. Salesmen must be realistic in their attempts at stimulating consumer preference. Motivation-research studies clearly

indicate that for a vast number of products, styling determines the level of sales. The style factor, in turn, necessitates an increase in the available varieties. This pressure for novelty also forces the product development and design departments to devise new and better products. In turn, the manufacturing department must make the necessary adjustments in its production methods and equipment. From the foregoing it should be clear that innovation is antithetical to both simplification and standardization.

The first concerted effort in this country in effecting a program of simplification and standardization in the commercial and industrial spheres was a direct result of the experiences arising out of World War I. By 1921 the recognition that waste in industry had to be reduced to a minimum led to the establishment of the Division of Simplified Practice as an adjunct of the National Bureau of Standards. This division, subsequently incorporated into the Commodity Standards Division, Office of Industry and Commerce, U.S. Department of Commerce, has published about 250 Simplified Practice Recommendations. Illustrative of the Division's work were its recommendations to reduce the varieties of warm-air-heating pipes, ducts, and fittings from 5,080 to 1,225; the varieties of wire rope from 352 to 182; and the varieties of grinding wheels from 715,200 to 254,400.

Despite the continuing attempts to secure a greater degree of standardization through simplification, there appears to be no danger that the American public will be restricted as to the goods it prefers to buy. Economic, aesthetic, and psychological factors exert unceasing pressures to find new and better products. As long as dynamism characterizes our economic system, the contest betweeen innovation and standardization can be expected to go on unabated.

COROLLARY 3. Interchangeability

In the synthetic-manufacturing process, that is, where component parts are assembled to form a finished product, standardization is synonymous with interchangeability. The term *interchangeable* in a broad sense refers to products or parts which are relatively equal in respect to the attributes requisite to the satisfaction of specific human wants. In a more limited sense, materials and products are interchangeable when one item can be substituted for another with no negative consequences. This can be accomplished only when all important variable factors are kept within relatively rigid tolerances so that substitution does not affect efficient functioning. Obviously, the interchangeable items need not be absolutely identical. However, as technology progresses, the limits within which variance is permissible

have tended to decrease to the point where, in the precision-goods industries, we even speak of tolerance measured in millionths of an inch.

Interchangeability, as an integral component of modern industrial processing, had its beginning with the momentous letter written by Eli Whitney on May 1, 1798, to Secretary of the Treasury Oliver Wolcott. In this letter, Whitney proposed to manufacture 10,000 or 15,000 muskets for our government. Because of the Napoleonic Wars, there was urgent need for arms, a large portion of which had, up to this time, been imported from Europe. Whitney's offer was considered fantastic by the experts, who assumed that no change in the technique of custom making of muskets was possible. Whitney's proposal was revolutionary, however, in that water-powered machinery was to be used in operations such as forging, rolling, boring, etc. The time-consuming manual operations were also to be reduced drastically by a specialization of labor so that one worker would perform only a minimum number of operations. Basic to his manufacturing method was the standardizing of production operations and the narrowing of tolerances for the dimensions of the component parts.

The concept of interchangeability of parts through standardization was not devised by Whitney. For example, Thomas Jefferson wrote in 1785 to John Jay, then Secretary of Foreign Affairs, describing an experiment by a French citizen, Leblanc, who anticipated Whitney's contribution by manufacturing musket locks through the assembly of interchangeable parts. In one of the demonstrations Jefferson himself selected components at random from pieces arranged in proper compartments and put together several musket locks. Jefferson even sent Jay samples of the product thus assembled.

Whitney also was acquainted with the manufacture, in certain New England plants, of products such as nails and card teeth which were made in standardized forms by relatively mechanical processes. Considerable work had also been done in England on the use of interchangeable pulleys.

There were tangible results from Whitney's exploration into the little-known areas of industrial methods, and out of a relatively similar delving by Simeon North, in the manufacture of interchangeable pistol parts. The new manufacturing technique was based upon the assembly of component parts, machined to such tolerances that one part could be exchanged for a similar part without complicated fitting or further machining. The efficiency of such a technique soon became obvious. It permitted the substitution of machine-made components for what previously had been the work of an industrial artist. Since

artistic talent in the industrial sphere is a relative rarity, interchangeability provided an effective substitute for a rather scarce factor of production. The new process permitted the utilization of lower grades of labor and reduced the learning period to a fraction of the long apprenticeship normally required for mastery of a craft.

Since large sums of capital were needed to finance the building of the elaborate equipment, it became progressively more important to maximize the use of this equipment. This necessitated improved production control methods. The danger of obsolescence likewise became a perennial problem. Full utilization of capacity logically led to large-scale production.

The culmination of the increased manufacturing tempo and the widespread application of interchangeability has been our system of mass production. This technique is so well known that it would be superfluous to analyze it in detail. The characteristic features of mass production include (1) rigid standards, (2) interchangeability, (3) mechanization, (4) serialized, synchronized processing, (5) large volume, low unit costs, (6) low-profit margin per unit of product, and (7) mass marketing.

SIGNIFICANCE

The more obvious benefits of industrial standardization have been listed in the first portion of this chapter. In addition to these well-known benefits, industrial standardization has had more important, yet sometimes overlooked, effects upon our society. Because of the widespread application of the concept, our very way of life has been significantly modified. Industrial standardization might be termed the greatest cohesive force in providing the degree of homogeneity in tastes, thoughts, and actions requisite to the development and functioning of the American version of democracy. As was previously mentioned, Napoleon Bonaparte visualized the need for uniformity in the system of weights and measures as a prerequisite for national unity. Napoleon, however, apparently never fully realized that an extension of the same principles into the spheres of thought and action could result in a much greater degree of homogeneity in his citizenry's political and social aspirations.

It would almost appear ludicrous to refer to such commonplace items as soft drinks, drive-ins, baseball, television, and the like, as democratizing forces. Yet it must be realized that organization, by definition, implies a community of interest. While differences in opinion and independence in thinking and acting are essential to dynamic organization, it is evident that identity as to customs and habits is most

conducive to the willing acceptance of the basic tenets of any given organization. Although this might seem to be philosophical musing, it should be obvious that without the products, conveniences, modes of communication and transportation, etc., which are concomitants of our system of industrial standardization, our very way of life would be radically different.

Not only does industrial standardization affect our society and its constituents, it has also brought about major changes in its progenitor —the industrial enterprise. For example, there is a very noticeable correlation between the degree to which an industry's goods and services are standardized and the scale of enterprise within that industry. Heterogeneity in product is conducive to individual endeavor. Hence, as long as there is no compulsion to conform in the goods produced and the services rendered, the dominant forms of enterprise tend to be the individual proprietorship and partnership. As soon as technological and economic considerations warrant and as soon as standardization is put into effect, the advantages of incorporation lead to the replacement of many individual proprietorships and partnerships by considerably fewer corporations. While this tendency is sometimes decried by economists, politicians, and assorted trust busters, the forces responsible for this trend cannot be divorced from the desired benefits of industrial standardization. For example, just prior to the introduction of that epitome of standardization, Henry Ford's Model T, there were more than 150 producers of automobiles offering in excess of 2,000 different makes of cars and an even much greater variety of styles. Before the Model T, car prices averaged between $3,000 and $4,000. Ford's standardized product, introduced in 1909, sold at about $950. By 1925, when 1,600,000 Model T's were marketed, the price had been cut to $260. There is no denying the benefits of this application of industrial standardization. However, as a direct consequence, the field of competitors in the automobile industry has steadily been narrowed until at present there are only three major corporations and several rapidly fading smaller concerns. Even the field of independent parts makers, once numbering several thousand, has now dwindled to less than 400 companies. As standardization in the field of automobile accessories and component parts progresses, the probability is high that the present relatively small number of suppliers will be further decreased.

Even in a product such as beer, which is so intimately related to individual taste, comparable changes have followed the shift of consumer preference from highly differentiated beers to a standard-tasting beverage. The 2,000 breweries operating at the turn of the century

dwindled to about 1,000 units just prior to Prohibition. Of the 700 breweries that reopened after Repeal, less than 250 are in operation today.

While it is obvious that a complex of factors brought about this change in the predominant scale of enterprise in the various industries, the prime factor, which might even be called the efficient cause, is the competitive superiority of the standard product as compared with the custom-built product.

The consequences of this significant change in the size of industrial units have had ramifications in numerous other areas such as the acceptance of unionism, the growth of large-scale unionism, industry-wide bargaining, the introduction of fringe benefits, industry-government cooperation in ventures, better training techniques, etc. In summary, the widespread adoption of industrial standardization has had profound consequences upon our way of life. Whether all these consequences are beneficial is a matter of personal preference and opinion. There is no denying, however, that a significant contribution has resulted from the better comprehension and the application of this concept.

ILLUSTRATION 1. "How the Division of Labour Multiplies the Product" [2]

We shall next show how this division of labour occasions a multiplication of the product, or, which is the same thing, how opulence arises from it. In order to do this let us observe the effect of the division of labour in some manufactures. If all the parts of a pin were made by one man, if the same person dug the ore, (s)melted it, and split the wire, it would take him a whole year to make one pin, and this pin must therefore be sold at the expense of his maintenance for that time, which taking (it) at a moderate computation, would at least be six pounds for a pin. If the labour is so far divided that the wire is ready-made, he will not make above twenty per day, which, allowing ten pence for wages, makes the pin a half-penny. The pin-maker therefore divides the labour among a great number of different persons; the cutting, pointing, heading and gilding are all separate professions. Two or three are employed in making the head, one or two in putting it on, and so on, to the putting them in the paper, being in all eighteen. By this division every one can with great ease make 2,000 a day. . . .

But again, the quantity of work which is done by the division of labour is much increased by the three following articles: first, increase of dexterity; secondly, the saving of time lost in passing from one species of labour to another; and thirdly, the invention of machinery. Of these in order:

[2] Adam Smith, Selections from "Lectures on Justice, Police, Revenue and Arms." Delivered in the University of Glasgow as Reported by a Student in 1763. In S. Howard Patterson, *Readings in the History of Economic Thought,* McGraw-Hill Book Company, Inc., New York, 1932, pp. 42–44.

First, when any kind of labour is reduced to a simple operation, a frequency of action insensibly fits men to a dexterity in accomplishing it. A country smith not accustomed to make nails will work very hard for three or four hundred a day, and those too very bad; but a boy used to it will easily make two thousand, and those incomparably better; yet the improvement of dexterity in this very complex manufacture can never be equal to that in others. A nail-maker changes postures, blows the bellows, changes tools, etc., and therefore the quantity produced cannot be so great as in manufactures of pins and buttons, where the work is reduced to simple operations.

Secondly, there is always some time lost in passing from one species of labour to another, even when they are pretty much connected. When a person has been reading he must rest a little before he begins to write. This is still more the case with the country weaver, who is possessed of a little farm; he must saunter a little when he goes from one to the other. This in general is the case with the country labourers, they are always the greatest saunterers; the country employments of sowing, reaping, threshing being so different, they naturally acquire a habit of indolence, and are seldom very dexterous. By fixing every man to his own operation, and preventing the shifting from one piece of labour to another, the quantity of work must be greatly increased.

Thirdly, the quantity of work is greatly increased by the invention of machines. Two men and three horses will do more in a day with the plough than twenty men without it. The miller and his servant will do more with the water miln than a dozen with the hand miln, though it, too, be a machine. The division of labour no doubt first gave occasion to the invention of machines. If a man's business in life is the performance of two or three things, the bent of his mind will be to find out the cleverest way of doing it; but when the force of his mind is divided it cannot be expected that he should be so successful. We have not, nor cannot have, any complete history of the invention of machines, because most of them are at first imperfect, and receive gradual improvements and increase of powers from those who use them. It was probably a farmer who made the original plough, though the improvements might be owing to some other. Some miserable slave who had perhaps been employed for a long time in grinding corn between two stones, probably first found out the method of supporting the upper stone by a spindle. A milnwright perhaps found out the way of turning the spindle with the hand, but he who contrived that the outer wheel should go by water was a philosopher, whose business is to do nothing, but observe everything. They must have extensive views of things, who, as in this case, bring in the assistance of new powers not formerly applied. Whether he was an artisan, or whatever he was who first executed this, he must have been a philosopher. Fire machines, wind and water-milns were the invention of philosophers, whose dexterity too is increased by a division of labour. They all divide themselves, according to the different branches, into the mechanical, moral, political, chemical philosophers.

Thus we have shown how the quantity of labour is increased by machines.

QUESTIONS

1. What connection is there between the division of labor as described by Adam Smith and the concept of standardization?
2. What are some of the negative by-products of division of labor?
3. Can the increased productivity per man-day resulting from the division of labor be ascribed entirely to the better utilization of manpower?
4. What influence does the market have upon the degree to which division of labor can be practiced?
5. Does division of labor have any ramification in the sphere of organization structure and policy?

ILLUSTRATION 2. Standardization in Chess

There is only one game of chess. There is the board, standardized as to size, 15 to 16 inches square, just 64 squares, 32 pieces, each with its definite rights of movement. It looks like a very limited and standardized condition, yet possibilities of operation are so infinite that if all the inhabitants of the world played chess continually from now until the end of time, they could not exhaust all the variations, thus experimentally determining which was the best possible game, that in which each player makes the best possible attacking and resistant moves, yet the total number of squares traveled is a minimum. It might be a long drawn-out game and it might be a short one—who knows, how shall we ever know? If, therefore, there is such infinite variety and possibility in chess, which has been played for centuries, how can we expect shop operations to standardize themselves? [3]

QUESTIONS

1. Do you think Emerson meant the last sentence of this excerpt to be a rhetorical question?
2. Considering the standardized aspects of the chess game, what accounts for Emerson's conviction as to the relatively infinite number of possible variants in games played?
3. Is the game of chess a good parallel of industrial standardization?
4. How might Emerson have modified this illustration if he had had contact with today's electronic computing equipment such as Univac?

ILLUSTRATION 3. "Take Zvezdin" [4]

The West last week got an exceptionally entertaining glimpse of the Soviet art world. The source: the Moscow newspaper *Soviet Culture*. Reporting on the Kharkov Art Factory, which produces handpainted copies of popular Russian pictures, the paper told how Factory Director G. V. Avrutin called a meeting to raise production. Said Avrutin: "Seven hours for a canvas of 57 by 84 centimeters [22 in. by 43 in.]? There is no need to waste so much time." Avrutin turned for an example to the task of copying *Morning in the Pine*

[3] Harrington Emerson, *The Twelve Principles of Efficiency*, The Engineering Magazine Co., New York, 1924, pp. 303–304.

[4] *Time*, Oct. 12, 1953.

Forest, a 19th century favorite by Ivan Shishkin. "The depth of the forest takes two hours; one more hour for the broken trees; for the pink sky, one additional hour. The four bears require not more than 15 minutes each. For general touching up, one hour more. The total," he finished, "makes six hours. This will be our new norm."

Then, according to *Soviet Culture,* a young artist stood up. How, he wanted to know, can you paint a little bear in 15 minutes and still make him lovable? The director replied sharply: "Quantity transforms itself into quality. . . . Take Zvezdin. For more than eight years the man has painted only Shishkin's *Morning in the Pine Forest.* Wake him up at any time in the night, and he will do the job better than Shishkin himself."

Director Avrutin's Stakhanovite methods produced more than 22,000 paintings this year, "but the quality, because of desperate hurry, is below any criticism." Concluded *Soviet Culture* sadly: "It is time for the Ministry of Culture of the Ukrainian Soviet Republic to take this factory under closer control."

QUESTIONS

1. What is your immediate reaction to Factory Director Avrutin's application of standardization?
2. What arguments might you advance in his defense?
3. In what other spheres of creative arts have similar practices been used with some success?
4. Is this example typical of the use to which standardization has been put in industry?

ILLUSTRATION 4. Preferred Numbers

Decisions relative to industrial standardization are largely a matter of sound judgment. Scientific management certainly would be facilitated if statistical techniques and similar tools were available to assist the decision maker in determining when, where, how, and to what extent he should introduce rigid standards. The following summary description of an arithmetic pattern generally referred to as the system of preferred numbers illustrates the type of techniques which could, in special situations, facilitate industrial standardization.

Preferred numbers refers to the arrangement of a series of numbers in some logical fashion, generally in a geometric sequence. In this series adjacent numbers retain a desired value relationship. The sequence is developed by applying a selected multiplier upon a base figure and upon all the resultant products. Thus the sequence 10, 20, 40, 80, etc., is derived by doubling, first the base numeral 10, and then the products of the multiplication. A similar series with a 1.5 relationship would consist of the numbers 10, 15, 22.5, 33.75, 50.625, 75.9375, etc. Comparable series can be set up retaining any desired

pattern. This geometric relationship is very useful in certain types of measurement of length, capacities, weights, volumes, diameters, areas, etc. It provides a uniformity particularly useful where interchangeability is important.

QUESTIONS

1. As an exercise in simple arithmetic compute comparable series within the range 1–80, on a base of 10, and with 1.75, 1.4, and 1.33 relationships.
2. What are some additional advantages which might follow from the industrial adoption of these standards based on geometric progressions?
3. What are the major limitations in the application of such standards?

ILLUSTRATION 5. Determining a Product Mix

While the preferred-numbers system is applicable to certain situations relating to measurement of proportions, there are serious objections to the introduction of comparable techniques in respect to commercial or performance standards. Although the following example pertains primarily to simplification, that is, the reduction in the number of unnecessary styles, sizes, etc., it does highlight the complexities involved in rigid quantitative analysis of subjective factors.

In a hypothetical firm which manufactures the eight products designated by the capital letters *A* to *H*, the three columns of percentages in Exhibit 4-6 refer to each product's ratio of sales, profits, and production facilities utilized.

Exhibit 4-6. Distribution of Sales, Profits, and Capacity Utilized among the Eight Products in a Hypothetical Firm (1954–1959 Averages)

	Percentage		
Product	Sales	Profit	Capacity utilized
A	20	26	21
B	42	31	36
C	1	3	2
D	11	18	14
E	4	0	3
F	3	1	1
G	13	19	13
H	6	2	10
Total	100	100	100

QUESTIONS

1. Show arithmetically your arguments for continuing or dropping the least important items.
2. What factors might impede simplification in this instance?

SELECTED READINGS. Chapter 4

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Moore, Leo B.: "Industrial Standardization," in W. B. Ireson, and E. L. Grant (eds.), *Handbook of Industrial Engineering and Management,* Prentice-Hall, Inc., Englewood Cliffs, N.J., 1955.

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CHAPTER 5

Organization Structure

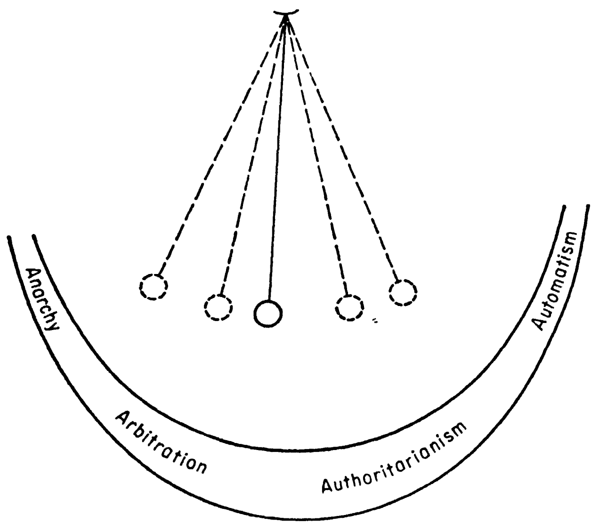
DEFINITION AND DESCRIPTION

Plato in Book II of *The Republic* depicts an organization as a large group of men acting as a unit at the behest of a single idea embodied in a single will. Organization would thus refer to any pooling of human physical and spiritual resources in order to facilitate the attainment of a predetermined goal. Presumably the concept of organization had its inception with the realization by the first human beings that concerted effort yielded disproportionately greater benefits compared with the sum of the same group's individual efforts. Thus organization is a means to an end. Invariably the ultimate objective, the character, resourcefulness, and resolution of the members, and the force of circumstance will determine the structural form, the personnel relationships, the dynamism, and the effectiveness of the organization. The same factors also regulate the degree of organization which can, theoretically, run the gamut from anarchy to automatism.

Actually, anarchy represents a complete lack of organization, while automatism is organization in the superlative degree. In practice modern organizations keep well within these extremes and gravitate toward either arbitration or authoritarianism. The former stresses democratic action, which generally produces a blending of all pertinent views into a compromise decision. The latter concentrates the decision making and the control functions in a single position or in the top level of authority. It is evident that there are many versions

of both democratic and authoritarian organization, with resultant modifications of the concepts of authority, leadership, and management. This intimate relationship between organization and closely associated concepts frequently results in a confusion of terminology. In the interests of simplicity and clarity, organization might be called the structure or the framework in which processes and relationships are embodied. Processes in this instance refer to the way in which

Exhibit 5-1. Pendulum Effect in the Degree of Organization



certain actions requisite to the attainment of the objective are performed. Relationships pertain to the official conduct of the organization's members both as individuals and as a group. The structural aspect of organization thus connotes a system both in the predetermined manner of performance of requisite tasks and in the hierarchical ranking of its members according to the importance of the functions they fulfill.

Although they differ greatly as to their functions and structure, there are certain characteristics common to all organizations. These general features include:

1. A body of precepts, rules, or regulations prescribing what is to be done and how, when, where, and by whom it is to be accomplished
2. Functional allocation of tasks to the various positions
3. A gradation of members, each being assigned a specific position
4. Investiture of specific authority and responsibilities in each position

5. Coordination of the various positional levels into a unified pattern or design
6. A system of communication as the means of coordination
7. An incentive system to induce maximum performance by the individuals

Although these seven factors apply to all forms of organization, our immediate concern is with their relationship to industrial organization. In summary, these characteristics apply as follows:

1. The body of precepts should obviously pertain to the basic objective of the organization and the means employed to attain this goal. Industrial organization, by definition, deals with the creation of utility through the production of goods and the performance of services. The rules and regulations of industrial organizations must therefore deal with the specific goods and services to be provided and the manner in which their production shall be undertaken. In relatively small organizations the body of rules and regulations might be handed down verbally and be interpreted as expediency dictates. In larger concerns, although certain areas of activity lean heavily on tradition, the great majority of all precepts are set forth in manuals dealing with specifications and with standard operating procedure.

2. Functional allocation of tasks to various positions is simply the application of the concept of division of labor to the aggregate organization. In a well-managed modern organization the responsibilities and the authority of each position are carefully delineated in a written job description. The technique of job evaluation, that is, the ranking of the various positions in their order of importance, is also generally applied.

3. By definition an organization is composed of a group of people; thus it can be assumed that the various positions in the organization structure must be staffed before any activities can be undertaken. In addition to staffing, serious concern must be given to the development of the member's potential to the maximum. Merit rating, promotion, seniority, and job training are but a few of the topics related to this aspect of organization.

4. The flow of authority from the top to the various levels within the structure is termed delegation of authority and responsibility. It is also the process of decentralization of management's functions, necessitated in modern industry by technical complexity and by growth in the scale of operation.

5. Subdivision of work, selection of personnel, and delegation of authority and responsibility do not automatically guarantee desired results. The fragmentized activities must be combined into a consistent

and harmonious action. This unification of the productive factors, of varying functions, and of delegated authority and responsibility is called *coordination*. After an organization has been operating for some time, most of the normal routine activities are coordinated by what is familiarly called *system*.

6. The smooth functioning of every organization depends upon the rapidity and the clarity with which information is relayed among the various units and individuals. Communication of commands or instructions, or as it is familiarly termed, the line of authority, goes from a higher to a lower level in the organization structure. The line of response, or of performance and accountability, follows an upward progression. These two basic lines of communication, downward and upward, are found in every organization. In addition there is cross communication, or an exchange of information between individuals at the same level. The growing scope of modern industry has magnified the need for functional communication, or the transmission of information and advice from ancillary departments and experts only incidentally connected with the basic functions of the organization.

7. Individuals normally have a reason for banding together. In the industrial sphere this motive is the maximizing of results of a joint endeavor, with a consequent increase in the shares accruing to the cooperating individuals. The group members must be convinced that the return is equitable and in excess of what they could individually earn. Although monetary considerations appear to have the greatest stimulus in the economic order, there frequently are nonmonetary factors which propel individuals into group action. The entire category of eleemosynary organizations, including educational, social, and religious groups, is generally motivated by noneconomic objectives.

These seven characteristics of organization structure, together with other pertinent aspects, will be analyzed in greater detail in subsequent chapters. The remainder of this chapter will be dedicated to a general consideration of authority as the force which knits organization into a meaningful whole. The next chapter will deal with considerations pertinent to staffing an organization. Before venturing into these two areas, it is in place to discuss here several phases in the development of both the structural and the staffing aspects of organization.

DEVELOPMENT

An analysis of the inception and early growth of the concept of organization would at best be highly speculative. The very antiquity of the concept, as can readily be inferred, particularly from what has

been said of the coexistence and codeterminance of organization and management, seems to imply a psychological genesis of both concepts. The instinct of gregariousness, in specific, serves to give satisfaction to those who associate and cooperate with others. Thus organization might be termed a functional design of life. Through the force of custom and law this design is transmitted from one generation to the next and becomes part of the cultural heritage.

Although it would be a lengthy and probably a superfluous task to trace the development of organization theory and practice, some attention should be focused upon certain aspects of the concept which have posed problems from the very beginning of recorded history. The ancient Greeks speculated at great length on the origin and the meaning of organization. Their philosophical musings frequently led to quite opposing views. For example, the views of Plato and Aristotle are contradictory as to which is preeminent—the individual or the organization.

Plato conceived the social order as a fabric of the human mind. He postulated that men knew what they wanted and that all society was simply a cooperative device to attain these wants. Once the goals and the means were determined, no deviations could be tolerated. In Plato's utopian city-state, the determination, promulgation, and enforcement of the organization's precepts were strictly the responsibility of the guardians—philosopher-kings and their specially trained subordinates. To Plato organization was utilitarian, conscious and purposeful, growing out of the perception of human needs. Man could be said to build society much in the same fashion that he builds his house.

Aristotle viewed society as the work of nature. The primary reason for the existence of organizations was not the perception of utility but the instinct of sociability. Utilitarian considerations were simply equivalent to by-products. Organization and all social relationships had their origin not in the brain of man but in his organic nature. By analogy, society was more of a growth than an edifice; it evolved in the manner of a plant growing in stature and complexity.

This philosophical disagreement has had very tangible repercussions. For example, the reestablishment of Aristotelian philosophy during the period of Scholasticism gave support from logic to the divine origin of authority. Aristotle's reasoning offered a seemingly irrefutable explanation for aristocracies and for slavery. If Aristotle's premises were accepted, improvements in organizational structure and procedures could be effected only by comparable modifications in human nature—and such changes were unthinkable.

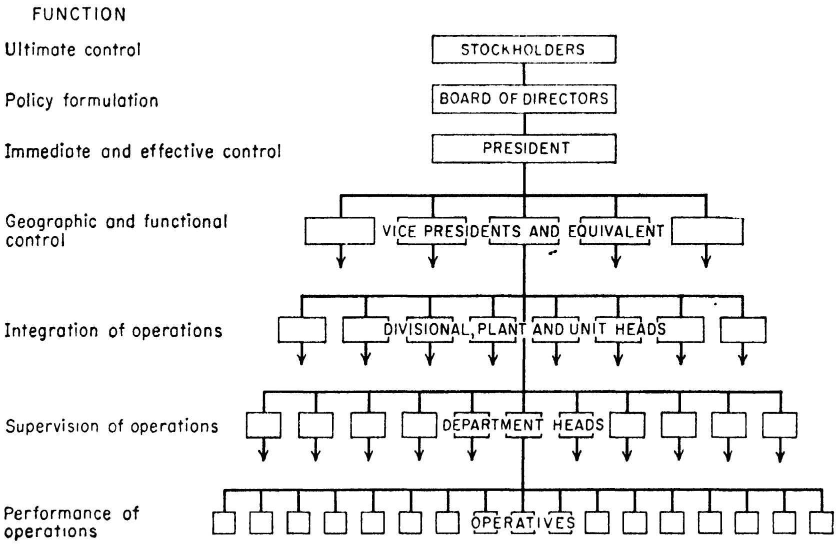
To Plato, the individual will was completely subordinate to the commonweal. This view has been the basis for labeling Plato as a proponent of authoritarianism. In his defense, however, it should be pointed out that he did advocate the downgrading of incompetent managers and the transposition of qualified members of a lower rank to the level for which their abilities qualified them. This stress on recognition of ability was in complete variance with the prevailing view that each man was born into his proper state in society.

The controversy over the relationship of men and organization was not confined to Plato and Aristotle. Zeno's Stoics accepted the inevitability of fate and advocated a doctrine of self-composure, of happiness through the inner harmony of the soul. Thus, in accord with Aristotle's views, one should accept his lot in society as determined by his level in the organization. Epicurus, conversely, stressed that society exists for individuals and is created by them. In this, he reflects the utilitarianism of Plato and lays the foundation for the doctrine of the social contract. Cicero reaffirmed this view by proposing a doctrine of the natural equality of men, holding that men differ in achievement but not in capacity. Where discrepancies do exist, they arise from abuses and not from nature itself. Cicero stressed that practically all human beings have innate powers that simply need to be brought into the open by proper guidance and education. Thus Cicero echoed the sentiments of liberty, fraternity, and equality nearly two thousand years prior to the French Revolution. Cicero's views were elaborated upon by a fellow Roman, Seneca, who emphasized that the lot of mankind, and even of slaves, is the result of the exigencies of fortune.

This philosophical disagreement, at first glance, might appear to be purely theoretical and of little concern to modern management. However, closer scrutiny would make manifest the similarity between the diametrically opposed opinions of the most eminent ancient philosophers and contemporary theories of organization. It is evident that in the United States both Plato's authoritarianism and Aristotle's aristocratic leadership are unacceptable in their original versions. Many areas of the world, however, have long subscribed to these views. Even in this country certain corollaries of the Greek philosophers' conclusions on the meaning of organization are quite evident. The basic issue of centralization of government is one such aspect. If, as Plato maintained, the State is supreme, then all authority flows from a central agency. If Aristotle's views are followed, then the natural origin of authority, despite the aristocratic connotations, lays greater stress on individuals.

together with a number of variations to accommodate specific needs. The most commonly used device, the vertical arrangement, is illustrated in Exhibit 5-2.

Exhibit 5-2. Vertical Organization Chart



Note: The vertical lines (↓) indicate a parallel flow of authority.

The second most prevalent form is the horizontal chart, used by many utility companies. Exhibit 5-3 indicates the progression of authority on a decreasing scale from left to right. This type of chart permits a more detailed description of the job duties entailed. It is, however, more cumbersome and less effective than the vertical chart.

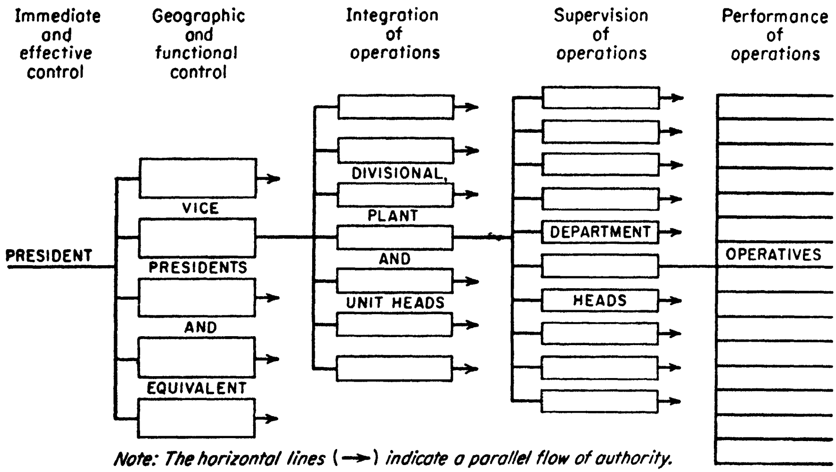
Regardless of its relative location, each position includes responsibilities pertinent to:

1. The coordination of all the activities inherent in that position with the activities of related positions
2. The application of standard-practice instructions in the performance of that position's tasks
3. The delegation of responsibilities and authority under certain specified conditions
4. The staffing of immediately related subordinate positions and the training of understudies
5. The "disciplining" of all personnel reporting to that specific position
6. The keeping of adequate records

Obviously, these duties will vary in degree depending upon the specific organization's background, its objectives, and the personnel staffing the various positions.

The widespread use of charts in depicting organization is tangible evidence of the effectiveness of this device. A note of caution, however, should be issued against the assumption that once the organization has been graphically depicted, "the neat little boxes with connecting lines" will ensure efficient performance. Henry Ford, probably one of the best-known proponents of centralized control, cautioned against too great reliance upon organization charts and similar control devices.

Exhibit 5-3. Horizontal Organization Chart



Note: The horizontal lines (→) indicate a parallel flow of authority.

Speaking of the genius for organization, he stated, "This usually results in the birth of a great big chart showing, after the fashion of a family tree, how authority ramifies. The tree is heavy with nice round berries, each of which bears the name of a man or of an office. Every man has a title and certain duties which are strictly limited by the circumference of his berry." [6] The chart, by itself, is merely a skeletal framework. This framework, to become operative, depends upon adequate staffing. Once the human quotient is injected, the need for constant reappraisal of the organization chart should become obvious. This characteristic is further described in illustration 1.

COROLLARY 6. Line and Staff

Authority and responsibility are frequently classified as either line or staff. The individuals performing the line type of authority have

[6] Henry Ford, *My Life and Work*, Doubleday & Company, Inc., New York, 1922, p. 91.

the power to issue orders to the work force carrying out the enterprise's main operations. Line officials likewise have the main responsibility for the success or failure of these operations. As has been previously mentioned, the expansion of an organization, together with the steady advance of technology, makes it virtually impossible for the line members of the organization to be acquainted with all the pertinent areas of activity. Thus growth and technological dynamism make division of work along functional lines mandatory. The individuals who dedicate their time to the fulfillment of these specialized functions are referred to as the staff. Theoretically, a staff man has no authority to give orders except to his own staff subordinates. His role is merely to provide technical advice and assistance to the line portion of the organization. The growing importance of the functional areas in modern industry, however, has resulted in elevating some staff positions to eminence. In the larger corporations it is the rule to have vice-presidents in charge of areas such as purchasing, finance, production, sales, industrial relations, and engineering. The number of such positions varies with the size, type, and policies of the individual companies. The expansion of certain staff activities has progressed to such proportions that these departments in turn have been forced to set up a "line" flow of authority and responsibility within the staff department.

Line authority is frequently referred to as the military type of organization. This is distinctly a misnomer since modern military organizations probably employ the staff setup to a greater degree than do any other forms of organization, including those in the industrial sphere. Staff officers fulfilling advisory or technical functions have been common to military organization for hundreds of years. The misapplication of the term *line* to the military probably arises from the inference that both are assumed to be autocratic.

The prime features of the line organization are its immediate concern with the performance of the enterprise's major activity and the delegation to the various department heads of the responsibilities and the authority to carry out all the steps requisite to that specific performance. This generally means that the foreman, for example, must not only direct the work but must also plan and schedule the operation, purchase raw materials, train the work force, keep cost records, and perform a great many other diverse tasks. Although the line type of organization is rigid and autocratic and puts an undue reliance upon the skill and accomplishments of individuals, it does have a number of advantages. Among these are its simplicity, stability, speed in response to stimuli, better discipline, and a clear-cut demarcation between levels of authority.

The first important modification in the conventional system of in-

dustrial organization was suggested by Frederick W. Taylor. Although his proposed "functional foremanship" never really had a valid test, the basic ideas have been adapted to modern industry. Taylor, after a careful study of the various activities performed by foremen and the attributes requisite to this position, decided that significant improvements would result from the application of the principle of specialization. He divided the conventional position of foreman into eight jobs, namely:

1. Time-and-cost clerk
2. Instruction-card clerk
3. Order-of-work and route clerk
4. Disciplinarian
5. Gang boss
6. Speed boss
7. Repair boss
8. Inspector

By this division all the benefits of specialization could be applied to foremanship. The first four functional foremen had charge of the mental and clerical functions, while the last four categories attended to the actual production in the shop. After several "pilot" applications of functional foremanship, the plan was abandoned because of its many limitations. For example, coordination was virtually impossible because of the overlapping authority and the inability to fix responsibility. The resultant friction dampened the initiative of both workers and supervisors. However, Taylor's suggestion set the foundation for the present-day integration of staff and line authority. The tangible results of Taylor's contribution in this field are evident in so far as:

1. The gang boss is now usually two men, the set-up man, and the move-man, trucker, or craneman.
2. The speed boss is the assistant foreman of today.
3. The repair boss has grown into the repair department.
4. The inspector has expanded into the inspection organization.
5. The time and cost clerk has developed into two units—the payroll department and the cost department.
6. The instruction-card man has become the time and motion study engineer.
7. The order-of-work and route clerk has developed into two sections—scheduling of work and machine loading, and the methods engineer or individual who plans procedures and prepares operation lists for the parts and assemblies.[7]

The foregoing is illustrative of how the old-fashioned type of foremanship has been affected by functionalization. A comparable special-

[7] Alford and Bangs, *op. cit.*, p. 17.

ization has been effected at other levels of management. In substance, then, Taylor's ideas have been instrumental in modifying industrial organization into the present line-and-staff hybrid. By its title, line-and-staff organization suggests a composite form which utilizes the better features of both components. In particular, the stress on specialization provides for a higher level of technical competence and a better utilization of managerial talent.

The limitations of line-and-staff organization are practically identical with those found in any functional division of work. If the areas of activity are not very carefully differentiated and if authority is improperly delegated, serious friction, particularly between line and staff groups, can result. Caution should also be taken to prevent the usurpation of control in the organization or any of its divisions by cliques of staff functionaries. Such improper concentration of control can easily follow from the placing of an exaggerated importance upon a specific function such as engineering or accounting. Dimock emphasizes this aspect, stating:[8]

> In some organizations where staff assistance is overemphasized, from the standpoint of both the influence and the number of staff officials, the chief executive is likely to be cut off from his department heads. An executive should never lose sight of the fact that his closest contacts must be with the heads of the operating departments, and that it is upon them more than any others that the success of the program depends. If he permits himself to become cloistered because of the more favored position of the staff officials, the morale and driving force of the program will be impaired.

In summary, the duties of the staff services should be restricted to providing advice in respect to:[9]

1. Research into technical, operating, or managerial problems
2. Determination and recommendation of the various standards of performance
3. Keeping of records and statistics on the above activities as a measuring stick of performance
4. Advice and aid in the carrying out of plans and programs

Properly utilized, the juncture of staff and line permits the most effective use of manpower through a judicious specialization at the supervisory and administrative levels. This specialization, or as it might more properly be termed, functionalization, fosters the more intensive application of technological and managerial abilities in the performance of progressively more complex economic undertakings. This is a prime requisite for dynamism in business and industry.

[8] Marshall Dimock, "The Meshing of Line and Staff," *The Executive in Action*, Harper & Brothers, New York, 1945, pp. 102–104.

[9] Alford and Bangs, *op. cit.*, p. 18.

SIGNIFICANCE

The process of industrial organization has been termed the most powerful instrument of education and of civilization. The attainment of objectives in industry requires the performance of long and disagreeable tasks. Such performance can be successfully carried out only if the human will is conditioned so that the future good is recognized as being preferable to present satisfaction. Thus the logic for organization rests upon the recognition of the laws of causation and the necessity for human cooperation.

Leaders in all fields of endeavor have generally been cognizant of the importance of sound organization. Andrew Carnegie's sentiments on the significance of sound organization are unequivocally expressed in the statement: "Take away all our factories, our trades, our avenues of transportation, our money, but leave me our organization, and in four years I will have reestablished myself." [10] Comparable statements have been made by other leading businessmen. The disintegration of once powerful industrial enterprises, such as The American Woolen Company and the United States Leather Company, testifies to the consequences of uninspired leadership and of poor organization.

Top-level administrators are currently giving considerable attention to both the broad area and the specialized spheres of organization. Practically every large corporation now numbers among its important departments a unit concerned with the problems of planning and control. Among the specific issues handled by such departments are questions relating to the division of line-and-staff authority, the extent to which delegation and decentralization can be effectively practiced, the span of control, improved communications, better coordination, and similar subjects. The creation of special departments for internal-organization analysis indicates that many modern executives accept the full and continuous responsibility of adapting the most up-to-date management methods to the needs of the organization. This is in direct contrast with the attitude, still frequently displayed, that unquestioning adherence to a preconceived stereotype constitutes organization. Similarly, organization planning and control departments indicate a confidence in one's ability to indulge in self-appraisal rather than rely on the diagnosis of outside experts or consultants. This is a healthy attitude. Organizational introspection by top executives is the surest way to find the means to effective group action.

Unquestionably, industrial organization exerts a powerful influence over our economy and our society. Some extremists maintain that the

[10] N. A. Brisco, *Economics of Business*, The Macmillan Company, New York, 1920, p. 76.

steadily growing importance of industrialization necessitates the closer integration of industry and government. The result would be a planned economy, paralleling, to a degree, the socialistic and communistic models. One of the first theorists to propose the establishment of the production-oriented state was the renowned French philosopher-sociologist Saint-Simon. Writing in the early eighteenth century, Saint-Simon advocated that the government of society be entrusted to chambers of professional men, industrialists, and scientists. The objective of this control of society by a small group of experts was to increase the nation's productive efficiency. In Saint-Simon's proposed "industrial system" incomes were to be distributed on the basis of contributions made by the respective individuals. A society stressing payment "to each according to his works" would, according to Saint-Simon, gain much from the regency of scientific, engineering, and industrial experts. Saint-Simon's ideas were further developed by the American economist Thorstein Veblen. These basic contributions formed the foundation for the establishment of technocracy, which was seriously proposed during the Depression. In the 1930s, Howard Scott and his Continental Committee on Technocracy, together with a group of engineers from Columbia University, conducted an energy survey of North America and concluded that the time had come to place the control of our economy in the hands of industrial experts—the technocrats. Their objective would have been the conversion of our economy from a price to a production basis. The logic of this proposal was founded in the belief that overproduction was the prime cause of economic depression. Overproduction could be eliminated, so claimed the technocrats, only when the control of government was in the hands of industrial managers. This proposal of the technocrats never received strong public support, and the plan, as originally set forth, has been abandoned.

Although it is unlikely that formal control of our government will ever be handed over to the technocrat type of administrators, significant strides have been made in the closer juncture of industry and government. The era of the New Deal and the Fair Deal were, in particular, marked by both a remarkable influx of the technocrat-minded experts into government service and the assumption by the Federal government of what formerly had been unquestionably industry's prerogatives. The government's demand for industrial management experts is indicative of the growing importance of industrial activity. This demand has in part been stimulated by the more stringent regulation of industry and by what some individuals feel is the usurpation of free-enterprise functions by government agencies. Irrespective of such controversial aspects, there is an obvious connotation that the

affairs of industry and of government are becoming more and more inextricably meshed. This subject will be more thoroughly studied in the chapter dealing with the control of industry.

ILLUSTRATION 1. An Insider's Organization Chart

This array of lines, squares, circles, lozenges, and rectangles shows some of the things that might happen to an orthodox organization chart if it were redrawn to reflect what actually goes on in a company in need of organization planning. The company, the Turbid Corp., is hypothetical, but most readers will recognize some familiar situations. Turbid's president is repeatedly asked to settle arguments among the manufacturing, purchasing, finance, and sales divisions, each of which wants its say on inventories. But the most frequent conflicts occur between these "line" functions and those so-called "staff" departments like engineering and marketing that exercise authority over the line through their specialized knowledge.

Turbid's aggressive managers, however, pay scant attention to jurisdictional distinctions. The industrial-relations department's authority, for instance, completely overlaps the personnel department because of (1) the president's enthusiasm for industrial relations, and (2) the emphasis on labor relations in the public utterances of Turbid's dominant board member. Similarly, Turbid's finance chief has so much drag with the president that his department cuts right across all decisions handed down the line of command. The dotted circle (upper right) symbolizes the post held by the fun-loving brother of Turbid's president, who is incapable of managerial functioning and dangles, the fruit of nepotism. The president is surrounded by committees, one so dominant it can give orders down the line as well as advice to him. His young "assistant to" in his confidential status colors much of what the boss hears from the twelve executives who jealously insist on reporting directly to the chief.[11]

QUESTIONS

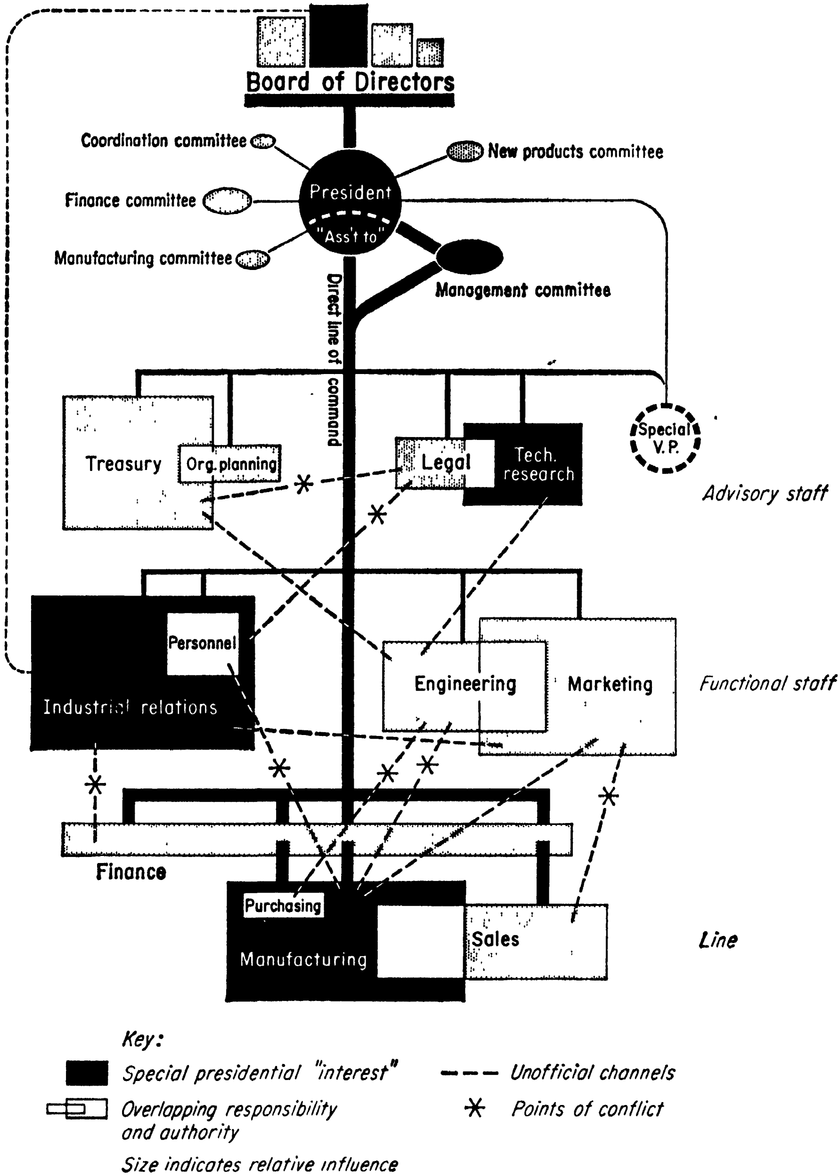
1. What steps should be taken immediately to remedy the distortions in this organization chart?
2. Is the present structural scheme sound?
3. Draw an organization chart for the hypothetical Turbid Corp. as it might have appeared when the concern was relatively small. What changes would you recommend if the company reaches the multi-million-dollar sales level?

ILLUSTRATION 2. Reorganization of the Ford Motor Company

Prior to 1946 the Ford Motor Company was "a vast, complex industrial system controlled and directed by a handful of men in Dearborn." Control was so concentrated that "the company was like an awkward, misshapen giant suffering from hardening of the arteries." Overcen-

[11] Perrin Stryker, "Can Management Be Managed?" *Fortune*, June, 1953, p. 101.

Exhibit 5-4



SOURCE: Perrin Stryker, "Can Management Be Managed," *Fortune*, June, 1953, p. 101.

tralization, inadequate definition of duties, uncertain lines of communication, overlapping authority, lack of performance records, and similar handicaps resulted in inefficiency and high cost. The former leader of the industry, at one time producing more than 50 per cent of the nation's automobiles, accounted for less than 20 per cent of the output in the postwar period. In 1937 the company averaged only $5 profit per car sold, while Chrysler's Plymouth and General Motors' Chevrolet had profit margins of $39 and $50, respectively. In 1946 Ford was losing money at the rate of nearly $9 million a month. When Henry Ford II took over the active leadership of the enterprise in 1945, he decided upon a sweeping reorganization based on decentralization.

R. E. Roberts, Ford Company's manager of the Management and Employee Information Department,[12] states that it was decided:

1. To relieve top management of the burden of routine operations.
2. To provide policies for the guidance of management.
3. To define the functions of each unit of the organization and to delegate responsibility and authority to the directing heads of the units.
4. To provide each executive and supervisor with the necessary tools of management, and
5. To establish a means of measuring performance.

What this meant, of course, was decentralization. It enabled us to draw upon the intelligence, the skill and the initiative not just of a few over-worked executives, but of thousands of capable men all down through the ranks of the organization.

It meant that all of our managers became managers in every sense of the word, with specific responsibilities and with adequate authority to carry out those responsibilities.

One of the first steps was to divorce staff and operating functions. What we were aiming at, essentially, was a line-and-staff organization with only policy definition and coordination by the Central Office Staff. . . .

The original Policy Committee of 11 men, which had been burdened with the initial review of every major problem that confronted our executive staff, had little time for the kind of long-range planning that was needed if we were to keep moving ahead on a sound basis.

So, in 1947, there were created a number of sub-committees, all of them to include additional personnel outside the original Policy Committee. The function of these new groups was to consider the more immediate operating policies and problems and to make recommendations to the main policy group. There are now ten of these sub-committees performing a vital staff function.

[12] "Ford's Reorganization: The Management Story," *Advanced Management*, May, 1954, pp. 10–11.

By 1952 operations had been broken down into 36 profit centers, each responsible for its output and prices. If, within the integrated system, one center charged too much for its products, other divisions could refuse to buy the component parts and place the order elsewhere. Each of the 36 profit centers was expected to report daily to headquarters, thus providing a check upon its semiautonomous units.

Roberts concludes his analysis as follows:[13]

> Today we have a top notch organization that has made and is still making industrial history. The awkward and stumbling colossus of 1946 has been broken up into a well-knit, closely coordinated team of semi-independent businesses operating with a minimum of Central Office policy control and guidance.
>
> Though our decentralized organization is still young and growing, all components have achieved much greater efficiency in planning and execution of operations. By delegating both responsibility and authority, we have built up our management strength at every level and, to a great extent, relieved our staff executives of the details of operating responsibility.

QUESTIONS

1. On the basis of recent performance would you say that the Ford Motor Company's decentralization program has been successful?
2. What major functions do you think could better be fulfilled under a centralized as compared with a decentralized system?
3. General Motors Corporation has beeen using this "centralization of major policy determination and decentralization of operational control" technique for more than thirty years. What factors might have delayed the Ford Motor Company's adoption of General Motors' successful experiment?
4. What obstacles do you envisage in the automobile industry, and in the economy as a whole, to continued emphasis on decentralization?

ILLUSTRATION 3. Parkinson's Law[14]

The London *Economist* in its November 19, 1955, issue carried an interesting commentary on the tendency toward proliferation of administrators. The article, reprinted in the March, 1956, issue of *Fortune,* despite a degree of facetiousness and some question as to the appropriateness of the label "Parkinson," highlights one of the most serious imperfections of modern organizational structure. On the basis of statistics relating to British governmental officials, the article indicates a 5¾ per cent average annual increase in staff personnel. An obvious inference follows: that such an increase is necessitated by growth and increased functional complexity. Parkinson's law refutes

[13] *Ibid.,* p. 12.

[14] Adapted from C. Northcote Parkinson, *Parkinson's Law,* Houghton Mifflin Company, Boston, 1957.

such contentions by declaring that the increase would be approximately the same regardless of the volume or complexity of the work to be performed. The law has two components: the law of multiplication of subordinates and the law of multiplication of work. The first component is based on the assumption that all officials eventually reach a point where they feel that they are being overworked. This feeling might be real or imaginary. Perhaps it is merely the symptom of advancing age. This feeling leads to alternatives involving (1) resignation, (2) dividing the work with a colleague, and (3) creating new assistant positions. Alternatives 1 and 2 are very seldom selected. Dividing the work with a colleague would soon result in a rival possessing equal authority. Thus the new positions must be created. Eventually this divisive process is applied to the subsidiary positions, accelerating the proliferation process.

The law of multiplication of work states that work expands so as to fill the time available for its completion. It is important to note that there actually is work to be done. The question arises: Is this work necessary for the efficient functioning of the organization? Simple inspection of practically any work situation would provide examples of reduction in accomplishment because of the number of extraneous and incidental activities. Once certain work routines, regardless of how unnecessary they are, have become established, they can only be abridged or eliminated by the equivalent of a violent reaction. The *Economist* cites as an example an elderly lady of leisure spending an entire day in writing and dispatching a single post card. She could spend an hour finding the card, an hour and a quarter in composition, and twenty minutes deciding whether she should carry an umbrella when mailing the card. "The total effort which would occupy a busy man for three minutes all told may in this fashion leave another person prostrate after a day of doubt, anxiety and all." Thus the multiplication of work pertains to the real expenditure of energy, even though such expenditure is inefficient.

As proof of its "law," the *Economist* cites the following statistics. Between 1914 and 1928 the British Admiralty had a decrease in commissioned ships from 62 to 20 and of officers and men in the Royal Navy from 146,000 to 100,000. These decreases were 68 and 32 per cent, respectively. Meanwhile, dockyard workers increased by 10 per cent, dockyard officials and clerks increased by 40 per cent, and Admiralty officials expanded from 2,000 to 3,569, a gain of nearly 79 per cent. By 1935, the Admiralty staff had reached a total of 8,118 officials, and by 1954 the number was a fantastic 33,788.

An even stronger argument is presented in the case of the Colonial

Office, where, despite the decline of Imperial prestige and power, there has been a steady rise in the size of staff. In 1935, only 372 Colonial Office officials were needed. By 1943, the number had risen to 817; in 1947 there were 1,139, and in 1954 the staff had mounted to 1,661.

Comparable illustrations are plentiful in our own government. The operation of the "law" in industrial enterprise has probably been less marked for a variety of reasons, chief of which is the perennial profit pressure. Nevertheless, the remarkable increase in ancillary positions and the significant decrease in the ratios of operating (or line) personnel to staff specialists provide a measure of confirmation. Caution must be exerted to counteract:

1. The tendency of functionaries to multiply themselves in geometric proportion relative to need
2. The tendency of peripheral activities to attain respectability by departmentalizing and expanding
3. The possibility that an administrator, because of loss of interest or inability to cope with his job, will acquire excessive numbers of assistants
4. The prevailing sentiment that a job's importance is gauged by the size of the work force supervised

In summary, every position should be compelled to justify its existence in terms of the basic organization objectives. Costs and benefits should be compared. Finally, if the job can be adequately fulfilled by another already existing position, the superfluous job should be eliminated.

QUESTIONS

1. Cite some instances where you believe Parkinson's law is operative.
2. What steps could be taken to make every position justify its existence?
3. Who should initiate a work force cutback program?
4. What dangers are inherent in any economy drive in respect to manpower utilization?
5. How does this illustration pertain to the concept of organization structure?

ILLUSTRATION 4(a). Montesquieu on Checks and Balances

Charles Secondat, Baron de Montesquieu (1689–1755), is generally credited with the classical formulation of the doctrine of checks and balances. Fundamental to this doctrine is the premise that in every organization there are centrifugal forces generated by vested interests, traditions, power cliques, and the like. Unbridled, these divergent forces rapidly destroy the organization by diverting individual effort into unintegrated accomplishment. Montesquieu's views on this subject were not entirely original. For example, the English philosopher

John Locke (1632–1704) stated that "It is necessary from the very nature of things, that power should be a check to power." Both Locke and Montesquieu exerted a strong influence upon the American republic's founding fathers. Tangible results include the tripartite division in our government with functions and powers so apportioned among the legislative, judicial, and executive branches that, theoretically at least, a most effective balance of power is achieved.

ILLUSTRATION 4(b). Washington on Checks and Balances

George Washington is quoted as saying, "The spirit of encroachment tends to consolidate the powers of all departments in one and thus to create, whatever the form of government, a real despotism. . . . The concentration of powers in one hand is the essence of tyranny." [15]

QUESTIONS

1. Do these views on checks and balances have any relevance to the typical industrial organization structure?
2. Comment on the inference that if "concentration of authority in one hand is the essence of tyranny," then the concept of ultimate authority is undemocratic and harmful to organizational effectiveness.

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[15] George Catlin, *The Story of the Political Philosophers,* McGraw-Hill Book Company, Inc., New York, 1939, p. 303.

CHAPTER 6

Organization Dynamics

DEFINITION AND DESCRIPTION

An organization structure might be conceived as a sort of harness by means of which the greatest pulling power or production potential of the several agents is obtained. Although this structural harness provides a means for binding the group members into a single working unit, such a bond is in itself no guarantee that the maximum productive power will automatically be attained. Organization dynamics, the process by which various structural components are vitalized and unified, pertains to the manner in which:

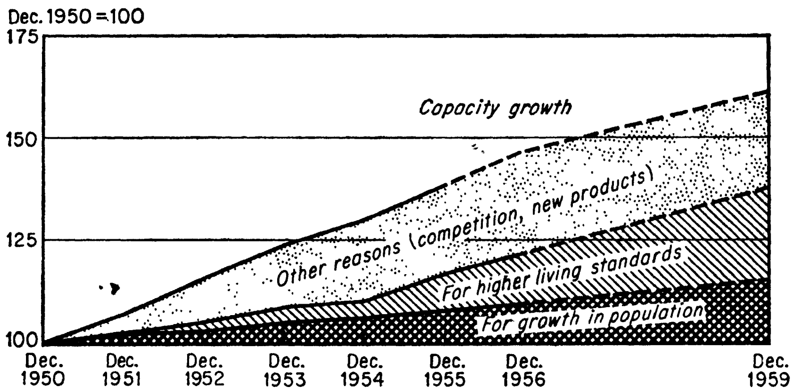
1. Qualified persons are selected to fill specific positions within the organization structure.
2. These individuals are then motivated to put forth their efforts to the maximum of their capabilities.
3. These maximum efforts are so integrated that the greatest group pulling power is obtained.

Capacity Factor. Capacity can be defined as the ability of an individual or a mechanism to perform specific actions. Capacity factor, in turn, refers to the extent to which available potential is, on the average, utilized. Thus a mechanism which could be used twenty-four hours a day but which, because of limiting circumstances, is actually employed only twelve hours per day has a capacity factor of 50 per cent. Obviously, this term is to a degree relative since conditions pertaining to time, place, objective, and means employed seldom remain

constant. Neither does a person's or even a mechanism's ability to produce remain unchanged over a long period. The effects of depreciation and obsolescence, that is, the physical wearing away or the economic deterioration of an object, tend to reduce capacity. Updating through a conscious program of modernization, on the other hand, serves to counteract the deleterious influence of both physical and economic degeneration. Similarly an individual's capacity or ability to produce is the sum of (1) his innate powers, (2) the degree to which he has cultivated these powers, and (3) the extent to which the developed abilities are maintained and improved.

Possession of productive capacity is not, however, a guarantee that such ability will be effectively utilized. On the contrary, maximum

Exhibit 6-1. Capacity Growth in Manufacturing Industry



SOURCE: *Business Week,* Mar. 23, 1957, p. 194.

exploitation of potential is a rarity in any sphere of human endeavor. It should be noted, at this point, that there is a very positive and direct correlation between the degree to which available resources are utilized, that is, the capacity factor, and the probability of success for the respective organization. It becomes a prime function of good administration:

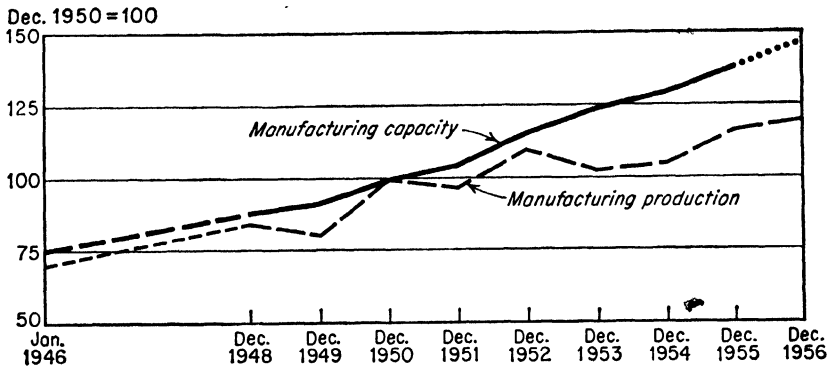
1. To make an inventory of resources or capacities
2. To strive to expand this inventory not only through new acquisitions but particularly through development of already available resources
3. To use these resources sparingly and in their most productive applications

Capacity factor can be expressed as a formula: $CF = P/Pa$, where P

is equal to the sum of the resources actually put to use and *Pa* is equal to the total resources available for use. If a stapling machine is capable, under normal operating conditions, of stapling 100 items per minute but because of a variety of circumstances output reaches only 36,000 units in a given 8-hour day, then the capacity factor would be computed simply as $CF = P/Pa = 36{,}000/48{,}000 = 0.75$. In this case the ability of the stapling machine to produce 100 items per minute during a period of 480 minutes was only three-fourths realized.

Exhibits 6-1 and 6-2 show how American manufacturing capacity has expanded during the last few years. The first of these charts allocates the increased capacity to the three most important initiating factors: growth in population, higher living standards, and dynamic

Exhibit 6-2. Manufacturing Capacity and Production



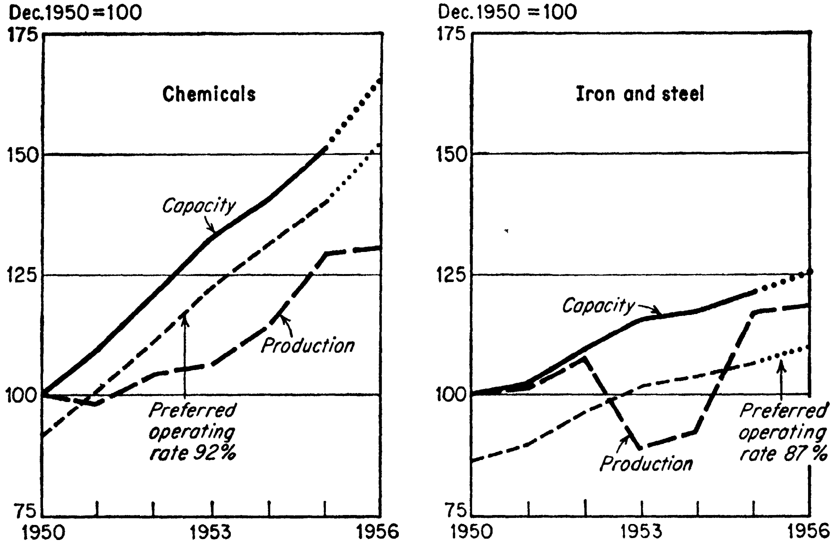
SOURCE: *Business Week*, Mar. 23, 1957, p. 192.

competition. The second chart clearly shows that despite a doubling in productive capacity during the decade, available capacity has not been utilized to the same degree each year. The capacity factor for 1946 could be estimated at approximately 95 per cent. In 1956 the capacity factor barely reached 80 per cent. Exhibit 6-3 indicates the extent to which two major industries, chemicals and steel, utilized their facilities during the period 1950 to 1956. The trend line labeled "preferred operating rate" designates the policy and practice of many industries of operating at less than full capacity. There are numerous reasons for such preference. Thus the theoretically perfect utilization of capacity, that is, a capacity factor of unity, is sometimes unrealistic, depending upon the interpretation of the term *ability to produce.* By analogy, a capacity factor of unity in the utilization of human resources might also seem to be an abstraction if the concept of ability to pro-

duce leads to gross exaggeration of potential or if maximum utilization has deleterious consequences.

Unfortunately, human abilities are far less subject to measurement than are machine potentials. Nevertheless, an effective administrator must be competent to appraise, at least within reasonable approximation, each of his group member's attainable potential. Even more important than such appraisal is the ability of the administrator to allocate, apply, motivate, and measure the use of such resources. In every instance a good administrator will strive to attain a capacity factor of 1, or unity, assuming such is desirable and attainable. Such attainment

Exhibit 6-3. Preferred Operating Rates in the Chemical and Steel Industries



SOURCE: *Business Week*, Mar. 23, 1957, p. 192.

means that the total realizable potential has been utilized since a capacity factor of unity indicates that total performance equals total ability to produce under present operating conditions.

Power Factor. From the preceding discussion it might be inferred that capacity factor is a function of (1) sound administrative judgment in appraising the availability of productive powers and (2) judicious scheduling so that the resources are made available and put to use. The concept of power factor focuses attention upon still another aspect of organization dynamics, namely, the equating of latent potential and usable potential. Latent potential refers to the maximum ability which, under optimum conditions, could be made usable. Unfortunately, op-

timum operating conditions are seldom a reality. Consequently, in most cooperative situations only a fraction of the latent potential is ever utilized. Human resources, in particular, tend to be ineffectively exploited because of countless limiting factors. At present it is practically impossible to assay an individual's maximum potential even with the most valid and reliable psychological tests. Then too, even if a fairly accurate index of potential were determined for a specific individual at a given point in time, such an index would not necessarily be accurate for subsequent periods when personal factors, such as elation, sickness, or fatigue, would have facilitated or curtailed the attainment of maximum potential. It is fairly obvious that even with machinery the absolute maximum productive ability is seldom realized. A myriad of factors, such as inadequate maintenance, improper location, faulty materials, untrained operatives, and similar handicaps, limit the optimum utilization of mechanisms. Similarly, obstacles of many kinds impede the full utilization of manpower within an organization structure. The obstacles now being considered are over and above those that follow from improper allocation or scheduling of resource use. The equating of latent potential and usable potential is much more than a mechanical function. It requires almost a mystic power to penetrate the minds of subordinates to get an index of their capabilities under optimum conditions. Nevertheless, an administrator, to be most effective, must strive to make his subordinates' underdeveloped or untapped resources more readily usable.

The concept of power factor has a rather technical application in the field of electrical engineering, referring to the loss of energy in electric motors and in an electrical transmission line. As a consequence, excess capacity is needed to compensate for such energy loss. By analogy, there is a tremendous waste of human energy in most organizations due to a multiplicity of causes such as:

1. Improper motivation
2. Inadequate communications
3. Underdeveloped technical potential
4. Maladjusted personalities

When a group member's maximum ability to produce is limited by any impediment whatsoever, it is fairly obvious that the group endeavor will likewise be hindered. The effective administrator will ferret out the factors responsible for the poor utilization of individual abilities and take positive corrective action. Such therapy has the effect of raising the power factor closer to unity. In this instance power factor $= Pa/Pt$, where Pa equals the potential actually available for use and Pt equals the total maximum potential which could be realized if

conditions were made optimum. Whereas maximizing the capacity factor ($CF = P/Pa$) depends largely upon mechanical measures, such as better scheduling, maximizing the power factor ($PF = Pa/Pt$) depends primarily upon intangible or subjective human factors. Some of these difficult-to-isolate and difficult-to-measure aspects, such as motivation and communications, will be appraised in several corollaries of this chapter.

In summary, this discussion of capacity factor and power factor highlights the three basic aspects pertinent to the generic concept of capacity:

1. Quantitative capacity is the holding power of the subject, in terms of some measurable extensive property and considered at a specific point in time.
2. Extensive, or rate, capacity is simply the quantitative aspect with the addition of what might be termed a fourth dimension, namely, a period of time.
3. Intensive capacity adds still another "dimension," quality, to the quantitative and extensive aspects of capacity. This qualitative differential, considered in reference to a great variety of attributes or characteristics, is frequently difficult to measure, yet of vital consequence.

Finally, a more intimate comprehension of the concept of capacity should be useful in:

1. Locating latent abilities.
2. Developing these latent abilities.
3. Making these latent abilities available for use. Success in this respect would yield a power factor approaching unity. In such a situation a person's ultimate potential to perform is recognized, developed, and made available for use.
4. Actually using the available resources. Perfection in this instance would provide a capacity factor of unity. Efficiency in this case would call for judicious planning and controlling of productive ventures.

DEVELOPMENT

The effectiveness of group action is intimately correlated with the capabilities of the group members, their zeal for the cooperative venture, and their talent for appraising situations, determining the best means for the desired end, and motivating the group members toward a maximum effort. In this context organization dynamics could be termed simply the control of human beings for achieving group objectives. In this sense organization dynamics is as old as the human race. Consequently, a thorough historical analysis of the subject would lead

back to the very wellspring of society. Such analysis is patently beyond the scope of this text.

The first systematic studies concerned with controlling the actions of men were made in the relatively broad field of politics. Initially this area encompassed, among other disciplines, what are now the distinct fields of philosophy, sociology, political science, economics, and the rudiments of industrial management. Most of the spokesmen of the ancient world assumed that the study of politics was simply the study of the control of human beings living in a cooperative society. This led the philosophers and politicians of the ancient world to emphasize the moral qualities, including harmony and social justice among all the participants in the group activity. Invariably these philosophical considerations propelled the students of politics to dream of hypothetical societies where moral, social, and economic perfection was attained with practically no effort. Plato's *Republic,* and to a lesser degree Socrates' *Atlantis,* were typical utopian visions. Even historians, purportedly recording facts, tended to inject their personal moral evaluations of historical episodes.

The first political scientist, in the strict sense of the term, was the Florentine nobleman by birth but republican by conviction Niccolo Machiavelli. His principal works, *The Prince, Discourses on the First Decade of Livy,* and *Florentine History,* were written in the first quarter of the sixteenth century. This was a rather turbulent era during which the Medici family strove to unify northern Italy under the leadership of Florence. The opposing forces of the other major city-states feuded against Florence and among themselves in an intermittent manner. Out of this era of turmoil, Machiavelli made some observations concerning the attributes and actions conducive to successful leadership. Machiavelli was not content to draw conclusions from individual episodes or from abstract moral precepts. Instead he supported his conclusions with factual illustrations drawn from history. Although Machiavelli's conclusions pertain directly to leadership of governments, these same conclusions are likewise applicable to every organizational venture.

Basically, Machiavelli was a realist divorcing, as much as possible, emotionalism, mysticism, and preconceptions from his recording of observed phenomenon. His stress on naked reality led less objective observers and sanctimonious partisans of particular causes to label Machiavelli as an atheist and a prophet of evil. Such condemnation is patently unwarranted.

The negative connotation of the term *Machiavellianism* follows

from the inability to accept the unpalatable truth that leaders are not necessarily infallible and all-virtuous. It is unfortunate that Machiavelli is so often considered the proponent of the use of any means, fair or foul, in the attainment of organizational objectives. Such an interpretation of Niccolo Machiavelli's teachings is one-sided and inadequate. Lichtenberger states that:[1]

> *The Prince* contains a philosophy of emergency and of crisis—that the end justifies the means—a doctrine in theory always repudiated but in practice always followed. Mankind has always a weakness, if it is a weakness, of making virtue a necessity. Inexorable conditions, not theories, if we observe the lessons of history, shape public policies. . . . Despite our denial that it is ever right to do evil that good may come, it would require volumes to record instances in which individual and public morality has justified exceptions to the rule. Machiavelli's fault was that he accepted this doctrine without apology, that he described it without equivocation.

Most analysts go so far as to recognize several very positive contributions stemming from Machiavelli's candid commentary on Lorenzo (The Magnificent) d'Medici's exercise of control in medieval Florence. It is generally agreed that Machiavelli gave impetus to the inductive method of analysis in the broad field of organization control. His stress on empiricism emphasized the importance of realism and of objective facts in the determination of organization structure and function. Machiavelli, in his use of illustrations and deductions to show the nature of organization in the principalities of his day, was the forerunner of the now very popular device of instruction by the case method. His microscopic analysis of the attributes which contribute toward success in the management of group endeavor sets the pattern for future scholastic and professional analysis of leadership traits. Without this callous yet absolutely essential emphasis on objectivity, there can be no sound basis for the science of management.

In the three centuries which have elapsed since Machiavelli made his rather radical observations on the realistic aspects of successful leadership and sound organization, the newer sciences, such as sociology, economics, and industrial management, have become divorced from the generic field of politics. Jeremy Bentham (1748–1832), founder of the Utilitarian School, injected the sense of realism into the sphere of economics. Auguste Comte (1798–1857), following a precedent set by Saint-Simon, earned for himself the title of Father of Sociology by his scientific analysis of group dynamics. In the sphere

[1] J. P. Lichtenberger, *Development of Social Theory*, Appleton-Century-Crofts, Inc., New York, 1938, pp. 136–138.

of government itself, the resurgence of the doctrine of the social contract, which gave rise to present-day democracies, developed out of the analytical and even skeptical spirit which rejected a priori premises.

In the field of faith and morals, the questioning attitude led to the religious upheavals of the Reformation period. The science of industrial administration, as described in Chapter 2, has also developed from the critical analysis of data provided by the grim realism of actual operating situations. Taylor's philosophy is identical with Machiavelli's in at least this one respect: that effective organization depends much more upon appraisal of all pertinent variables than upon the establishment of postulates and preconceptions purportedly stemming from absolute truths or values.

Machiavelli's contribution to the better comprehension of effective organization has been singled out to call attention to the slow evolutionary process in which basic concepts develop. From this fragmentary historical presentation it can readily be inferred that most of the currently popular ideas and practices relating to the effective control of industrial organization have evolved out of philosophical speculations.

COROLLARY 1. Leadership

Despite the fact that there have been leaders from the very first banding of human beings into group ventures, no satisfactory formula for leadership has ever been devised. A commonly proposed precept stresses that a good leader always subscribes to the dictates of his followers. Such a course of action might be commendable, but the question arises about the frequency of unanimity of sentiment. Differences of opinion are invariably found within every group. It is the function of the leader to choose from these diverse opinions, and from all other alternatives, the course of action to be followed. It must be emphasized that even when the leader acquiesces to the will of the majority there is no assurance that the best alternative has been selected. History provides countless examples where mass sentiment degenerated into mob action and the espousal of questionable causes. Even Moses, leader of the ancient Jews, after receiving the Decalogue inscribed on tablets of red granite, came down from Mount Sinai to find his followers in a wild Bacchanalia. The sentiment of the majority of Moses' band, expressed in their willingness to follow the wicked Dathan in the worship of the golden calf, is an example of the danger leaders face if they too readily yield to popular sentiment. A list of now abhorred, but once popular, practices and beliefs, including the Inquisition, trial by combat or by torture, dueling, slavery, witch burning, divine right of

monarchs, suttee, and a very large number of equally reprehensible customs, would seem to corroborate this premise.

It has also been demonstrated that the majority sentiment in any group generally coincides with what might be termed the *status quo.* This sentiment is antithetical to change and dynamism. Yet in any competitive situation adaptation to changing circumstance is vital to survival. Thus a good leader must very frequently strive to modify his group's *status quo* sentiments in the light of new ideas and ways of action.

Another aspect of the difficulty in defining leadership is the heterogeneity of this function. Differences in organization objective, organization structure, geography, custom, time, personality, and socio-economic-political circumstance dictate the need for varying attributes in the men selected as leaders. Thus it can safely be asserted that there is no single type of leader that might be considered the paragon for all organizations. Good leaders must be custom-built to fit the needs of the specific organization.

Despite this emphasis on heterogeneity in respect to leaders and leadership traits, there are certain attributes commonly found in all good leaders.

1. Sound leadership is synonymous with effective decision making. In every situation where a decision must be made there are two sets of factors, the variable, or limiting, factors and the constant, or complementary, factors. The latter can more readily be isolated and appraised. In a relatively static situation even a mediocre leader can lead his group without serious injury to himself or to the organization. On the contrary, dynamic situations practically always accentuate the incidence and the importance of variable factors. In such cases the leader must be competent to interpret the meaning of these variable factors, their potentials, and their consequences. From the foregoing it should be evident that dynamic situations present a greater complex of variable factors, and consequently a higher type of leader is needed. In our present rapidly changing society this means that good leaders must be adequately schooled in the many technical phases out of which the variable factors are generated. Because of its importance to improved leadership and to effective management, an entire chapter will be devoted subsequently to the more technical aspects of decision making.

2. Sound leadership implies the function of determining organizational objectives. Once again, in a relatively static situation, this function can be performed in a perfunctory fashion since custom and related forces in such cases provide a readily usable pattern by which the leader can almost effortlessly make his decisions. Where conditions

are in flux, however, there is a heavy pressure placed upon the leader to interpret the customarily accepted objectives in terms of the dynamic situation. Consequently, a good leader must be thoroughly acquainted with his organization's objectives, with internal and external forces which might lead to modifications in objectives, and with the consequences and advantages of such adaptations.

3. Closely associated with the previous attribute is the ability of a good leader to manipulate the means at his command to the best possible group advantage. Obviously, this implies a thorough acquaintance on the part of the leader with the technical aspects pertinent to the organization's attainment of its objectives. There is a sentiment prevailing in many quarters that, because of the complexity of modern industry, industrial leaders need know nothing about the various functional activities encompassed within the organization. This gives rise to an equally erroneous view that a leader need simply be a person who can get along with his fellow men. Such sentiment is patently wishful thinking on the part of mediocre individuals who aspire to leadership but are unwilling to undertake the difficult preparatory phases. Although a modern industrial leader can scarcely be an expert in every functional area of modern industry, he must possess, in addition to a likable personality, technical competency. If he is not thoroughly schooled in at least the basic terms, concepts, and principles of the most important functional components of modern industry, he can scarcely be expected to comprehend the nature of business problems and business objectives.

4. Effective leaders invariably develop efficient organization structures and make use of these structures. In this capacity, the leader must select and develop the highest-caliber subordinates and imbue them with ideals and attributes comparable to his own. Proper use of an organization's structure also implies an alignment of positions logically arranged so that each function of the organization can be performed with a minimum of effort. This alignment of positions must also provide for a facile flow of authority and responsibility. The relationship of successful leadership and sound organization structure should be manifest from the description in the preceding chapter.

5. Leadership implies the power of stimulation toward coordinated action. Unless, in addition to delineating the desired objectives, a leader can move the group into unified action, there is very little probability of success. The means employed in group motivation vary widely. Some group members act because of fear, others act out of indifference, still others have the habit of obedience. More effective results are generally obtained when the group members perform out of

a sense of loyalty or because of a strong belief in the leader or in the organization. It is a function of leadership to determine the many, and at times even diametrically opposed, forces which impel the group members to perform. After a judicious analysis of all these innate impulses, the leader must then choose the means which will provide the greatest motivating force.

There have been numerous attempts at describing the essentials of good leadership. One of the more recent ventures was made by *Fortune*, which, after polling numerous successful industrial leaders, compiled a list of 99 definitions of the leader at the executive level. The respondents also described 115 executive actions requisite to good leadership. *Fortune* summarized[2] these numerous executive actions into the following 10 categories:

1. Achieving the company over-all objectives
2. Planning and setting policies and objectives
3. Making decisions, thinking, analyzing
4. Coordinating functions and people
5. Organizing and developing subordinates, advising other executives and managers
6. Handling subordinates, controlling operations
7. Improving one's own capacities, leading, setting an example
8. Delegating, giving orders, working through others
9. Exercising business judgment, performing a specialty
10. Dealing with the public

The question logically follows: What basic qualities are requisite to the fulfillment of these executive actions? Once again there are numerous listings, compiled by eminent authorities, which include every attribute and virtue imaginable. Nevertheless, these enumerations of leadership qualities invariably pivot around the following:

1. Technical proficiency
2. Creative imagination
3. Capacity for decision making
4. Personal magnetism

In addition to achieving desired objectives, good leadership enkindles the group members' zeal as to:

1. The superiority of the common purpose over individual interests
2. The probability of success of this specific group's attaining its objectives
3. The ultimate satisfaction of individual desires to the greatest possible degree through the realization of the common goal
4. The integrity of line authority in its decision-making capacity

[2] *Fortune*, December, 1955, p. 109.

Leadership has been termed the strategic factor in effective organization. It was previously stated that in any situation where individuals must make a choice from among several alternatives, there are two sets of pertinent factors. The first might be termed constant, or complementary, factors. The second are the strategic, or limiting, variable factors. With the increased complexity of modern industrial organization, it is logical to assume that the second category, the limiting variable factors, have become progressively more important. The most vital of all these limiting variables, or strategic factors, in the sphere of industrial organization is leadership capacity.

COROLLARY 2. Span of Control

The process of delegation has been described as an application of division of work to the managerial function. Complex tasks beyond the capacity of individuals can be accomplished through proper use of delegacy powers. However, it should be kept in mind that the allocation of duties to subordinate positions does not relieve the delegator of ultimate responsibility for satisfactory fulfillment of those duties. The delegator must consequently supervise the performance of his subordinates. The obvious question arises: How many subordinates can a superior properly oversee?

The outstanding contribution on this topic was made by Graicunas, who, in a paper published in 1933,[3] propounded a theory currently termed the span of control. Graicunas's contribution is unique in so far as he attempted to show numerically the geometric relationship between the increase in numbers of subordinates and the increased complexity of supervision. He assumed that there were three distinct categories of relationships: direct single, cross, and direct group. The first of these, direct single relationships, are generally assumed to be the most important. They are concerned with the attitudes and actions pertaining to the supervisor and a single subordinate. Thus, if in a specific situation a superior has four subordinates, it is evident that there are four distinct direct single relationships, namely, those between the superior and each individual subordinate. Increasing the number of subordinates means a similar increase in the number of direct single relationships.

While direct single relationships arise out of contacts between individuals at different hierarchical levels, cross relationships are restricted

[3] V. A. Graicunas, "Relationship in Organization," Bulletin of the International Management Institute (International Labour Office, Geneva, 1933) in L. Gulick and L. Urwick (eds.), *Papers on the Science of Administration,* Institute of Public Administration, New York, 1937, pp. 181–187.

to a single level. Thus the "power to command" has no direct bearing on these relationships. Instead, the latter arise out of factors such as physical proximity, mutual interests, or related functions. These cross relationships are very important to the effectiveness of organizational performance in so far as they are conducive or detrimental to the development of sound morale. Cross relationships are also vital to the exchange of pertinent information and of technical advice and assistance, without which no modern organization could function. Obviously it is physically and economically impractical to communicate every order and every item of information directly from supervisor to subordinate. Even more difficult is the direct provision of minor technical assistance by the supervisor every time the need arises. Thus

Exhibit 6-4. Increase in Interrelationships as Number of Subordinates Increases under the Span of Control

Factor in formulas	Number of subordinates									
	1	2	3	4	5	6	7	8	9	10
Values of A	1	2	3	4	5	6	7	8	9	10
Values of B	0	1	3	6	10	15	21	28	36	45
Values of C	0	1	4	11	26	57	120	247	502	1,013
Values of F	1	4	10	21	41	78	148	283	547	1,068

SOURCE: L. P. Alford and J. R. Bangs (eds.), *Production Handbook,* The Ronald Press Company, New York, 1955, p. 32.

cross relationships serve an economic function by stimulating or impeding the spirit of cooperation within the organization and by elevating or lowering the level of morale.

Direct group relationships compound the problems of effective organizational control. As the span of control widens, the number of direct group relationships increases at a rapidly accelerating rate. The reason for this is obvious since the number of different groups is limited only by the number of possible combinations of individuals at a given organizational level. In a situation where a supervisor deals with only two workers, there can be only one direct group relationship, namely, that between the supervisor and workers *A* and *B* together. Increasing the span of control to three means that the supervisor can now deal directly with the following combinations of workers, *A* and *B*, *A* and *C*, *B* and *C*, or *A*, *B*, and *C*. This rapid rise in direct group relationships is apparent in the figures presented in Exhibit 6-4.

Graicunas proposes the formula $2^N + \frac{N}{2}(N-1) - 1$ to determine

the total of all three types of relationships. This formula is obtained through the addition of the values ascribed to the three kinds of relationships where (1) direct relationships equal N, (2) cross relationships equal $N/2(N-1)$, and (3) direct group relationships equal $2^N - (N+1)$.

The obvious inference from the amazing increase in total number of relationships resulting from a widening of the span of control is that there must be differences of degree among relationships. In particular, as the number of direct group relationships grows disproportionately, it seems safe to infer that every direct group relationship does not have equal weight. Many of these subgroups vary in attitudes only in an infinitesimal degree. It seems obvious that an increase in the span of supervision from 5 to 10 individuals, although it results in a rise from a total of 41 to 1,068 total relationships, is probably not accompanied by a twenty-six-fold compounding of difficulty in supervision.

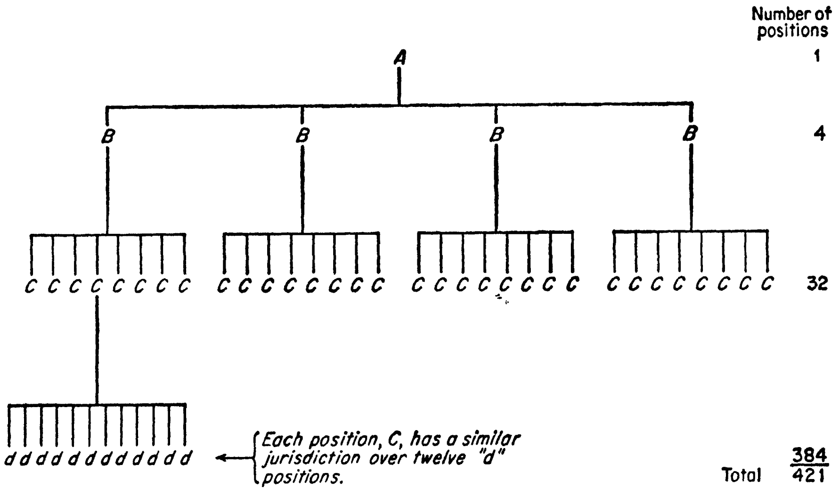
Other factors modifying this concept are variations in organization structure and objectives, external circumstances, and the character of the individuals concerned. Thus American industry provides examples of apparently well-run organizations with spans of control at the top level varying from 1 to more than 20. The Douglas Aircraft Company had, for a long time, no less than 27 executives directly responsible to its president. Although there are a few exceptional cases where the span of control is very narrow or extremely wide, there appears to be a consensus among top American executives that the ideal, at the upper level of management, should be somewhere between 4 to 8 subordinates. At lower levels this span can be effectively increased to between 8 and 15 subordinates. In exceptional cases the number might even be stretched to between 20 and 30 subordinates.

Exhibit 6-5 shows how a single administrator can maximize his usefulness by the judicious application of the concepts of delegation and span of control. In this instance only three organizational levels, in addition to the top executive, are considered. The effective span of supervision for these levels from upper to lower is, for illustration purposes, assumed to be 4, 8, and 12, respectively. Space limitations prevent a complete schematic illustration. In this instance one administrator has jurisdiction over 420 individuals: 4 immediately responsible to him, 32 at the next level reporting directly to his four immediate subordinates, and 384 at the third level. Increasing or contracting either the span of control or the number of levels will affect the size of the particular organization. In turn, such modifications will have a bearing upon qualitative aspects relating to performance.

From the foregoing, it can be inferred that effective organization is closely correlated not only with the breadth or span of control but

also with the depth of control as manifest in the number of hierarchical levels. This latter aspect is likewise subject to conjecture. During wartime emergencies, military organizations have functioned with approximately 13 levels. Most industrial enterprises tend to restrict to 6 or less the number of distinct levels of authority. Wide variance in salary, in title, and in functions complicates the clear-cut delineation of hierarchical levels.

Exhibit 6-5. Hypothetical Four-level Organization, with 1, 4, 8, 12 Progression in Span of Control



In summary, the dual concepts of span of control and levels of authority are subject to countervailing forces:

1. A tendency to widen the span of control and to increase the levels of authority, thus maximizing the use of administrative and supervisory talent.

2. (*a*) Pressure to minimize the number of subordinates within a specific jurisdiction, thus accentuating the benefits of direct personal contact; (*b*) a realization that too long a chain of command invariably leads to ineffective communications and inferior performance

COROLLARY 3. Communication

Communication is the act of conveying information by means of which thoughts or opinions are interchanged. As indicated in previous chapters, there are three basic directions in which communications can be sent within an organization: downward, upward, and crosswise. The downward flow of communications, closely associated with the

exercise of authority, is generally concerned with the promulgation of new decisions, the clarification and interpretation of previous decisions, and requests from superiors for specific information. The upward type of communication deals with the response to orders from superiors, the upward transmittal of information, and requests from subordinates for higher-level decisions on operating problems. Cross communication occurs among individuals at the same organizational level when advice relative to organizational activity is sought or given to fellow workers, or when information of any sort is transmitted via the grapevine. An example of how one form of cross communication can be of real value to an organization appears in the classic description of Fayol's bridge as presented in illustration 1.

In the discussion on the power factor it was pointed out that maximum ability to perform can be reduced by either internal or external impediments to the transmittal of orders and ideas. Thus if a worker has difficulty in hearing, there is an increased probability that he will misunderstand or even fail to hear some of the verbal communications. Students from foreign lands will invariably have impaired scholastic achievements unless they take steps to improve the communications media by getting better acquainted with the language in which the course work is being presented.

Among the factors which condition effective communications are the following:

1. A capacity within the person seeking to transmit the information
2. Judicious selection by the communicator of what is to be transmitted
3. Clear and direct channels of communication
4. Adequate media for communicating
5. Proper timing and proper use of the media
6. Adequate relay stations or relay agents when needed to facilitate the transmittal of the original message, undiminished, unchanged, and in the proper direction
7. A capacity and a willingness within the receiver to accept the message
8. Receipt of the information and proper interpretation
9. An effective application of the information
10. Notification to the sender of the results of the action

In substance, communication is simply an actuating device, that is, a means by which a specific group gets into action following the leader's directive. It is distinctly only a means to an end. Although effective communication is practically mandatory for successful accomplishment, it should be pointed out that effective communication by

itself does not guarantee effective performance. Considerably more is needed for the attainment of organizational objectives than the simple conveying of information. It should also be evident that not all information need be communicated. The relatively recent fad of "participation" highlights this point. Some executives, under the impression that subordinates will be highly motivated if they are informed about everything, send so heavy a downward flow of information that the deluged recipients become confused. Where the reciprocal flow of information is lacking, it is highly doubtful that the downward transmission of information, regardless of its volume, will be very effective.

Human Aspects. During the past decade considerable attention has been given to both the mechanical and the nonmechanical aspects of communication within industry. The nonmechanical considerations are intimately associated with the changing role of the corporation in modern society. In addition to being the most efficient organization for large-scale production and distribution, the corporation has also become a quasi-autonomous community. This new version of community life has its own peculiar social structure, complete with codes, allegiances, customs, taboos, and status symbols. Most remarkable in this evolutionary change is the injection of democratic principles into the authoritarian discipline of industrial organization. Some of the more visible manifestations of this change are relatively recent innovations such as welfare and pension plans, seniority provisions, wage and work stabilization, elaborate public-relations programs, and the like.

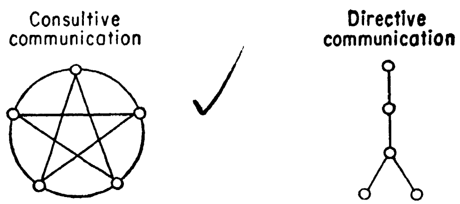
This more recently emphasized aspect of communications is concerned with the development of a better working environment. With improved work relations and conditions, it is assumed that morale and performance will be boosted significantly. Any shift from the rigid discipline formerly assumed to be an integral part of industrial organization to a more democratic approach in resolving management problems must of necessity involve a modification in the channels and modes of communication. This impact of human factors upon organization structure has been evidenced in the sections treating of the power factor, personification of the organization, and informal authority.

Complexities in communicating must invariably arise when unwritten codes develop. For example, managerial control can be seriously abridged by practices akin to the mob-rule ostracism which workers generally impose upon a "rate buster" who has violated the group-imposed work quota. Of necessity authoritarian modes of communication must take cognizance of the reality of such unofficial, yet rather

effective, group sanction. This injection of what some individuals consider democratic collective action and what others label demogogic socialism has evoked much controversy in recent years. "Groupthink," brainstorming, multiple management, consultive management, and a great variety of kindred innovations, all deal with the increased participation of employees in the making of managerial decisions.

One of the surprising discoveries from recent studies of participation is a theory that happiness at work and high morale do not necessarily result in better performance. Such views would seem to cast some doubt upon the inferences drawn from the classic Hawthorne Experiment of the Western Electric research program.

In particular, the experiments of Dr. Alex Bavelas and a group of Massachusetts Institute of Technology psychologists highlight this heretical view. In one especially interesting experiment, Bavelas used two distinct control groups having two polar opposites of organizational structure. Each group had five members. The first group was



so constituted that the members communicated with one another in what is termed a circular pattern. The other group followed the customary line type of control. After being presented with identical problems, it was discovered that the circular-pattern group was much happier but far less efficient. The hierarchical group, although less happy, was superior in performance. It might be inferred from this and similar experiments that high morale is not necessarily synonymous with superior performance.

Despite this apparent disillusionment, there seems to be a steady move toward greater acceptance of the participation concept in the hope that both morale and productive efficiency will be improved. Even if the Bavelas type of experiment should be validated, there seems to be ample indication that organizations will continue to give morale stimulation increased attention. The recognition that industrial organizations have other than economic functions is the basis for this view. Although there is no denying that dollar-and-cents considerations are still paramount as integrative forces in industrial group venture, there is a growing body of evidence that industrial organiza-

tions have assumed new dimensions in their transformation into quasi-independent subcommunities. A by-product of such reasoning is the growing acceptance of the belief that an industrial organization should provide more opportunities for the technical and the social self-improvement of its members. This and similar assumptions necessitate more effective communicating, upward, downward, and particularly crosswise, within every organization.

Mechanical Aspects. As industrial organizations expand, the mechanical as well as the human problems of communication become more acute. One single example is the tremendous increase to more than eight million in the number of clerical workers in the United States. It is the function of these clerical workers to connect management with production, sales, and research by recording, organizing, and collating the vast quantities of information pertinent to industrial activity. It should be pointed out that despite this significant increase in their numbers, the productivity of office workers has declined relatively. For example, one clerical worker was needed in 1940 for the production of approximately $47,000 (using current dollar value) worth of goods and services. Using the same dollar standard, a clerical worker still accounts for only about a $47,000 output.

The magnitude of paper communication is apparent from the Hoover Commission Report which estimated that before World War I, 400,000 government employees averaged 55 letters a year. Presently more than 2 million Federal workers average over 500 letters apiece each year. In addition to sending more than 1 billion written communications, the Federal government also receives annually in excess of 18 billion letters, etc., from its citizens and business enterprises.[4]

This staggering volume of paper work, together with the relative decline in clerical workers' productivity, has stimulated the development of revolutionary paper-work machines, using electronic devices for writing, recording, and performing elaborate computations. Some experimental electronic reading devices have also been built. General-purpose business computers, such as IBM's 702 and Sperry Rand's Univac I, have been supplemented by such special-purpose equipment as Stanford Research Institute's ERMA (Electronic Recording Machine Accounting). ERMA and a team of 9 operatives will, in theory, replace 50 bookkeepers in the handling and recording of bank checks.

The newer electronic communication devices supplement the recording and transmitting mechanisms which have been in use for some time. There should be no need to list the great variety of duplicating machines, industrial adaptations of the telephone, intercom systems,

[4] "The Coming Victory over Paper," *Fortune*, October, 1955, p. 130.

radio, and television. Among some of the more useful of the electromechanical communication contrivances are the following:

1. The teletype, an electrically operated typewriter, operates over a regular telephone circuit simultaneously typing orders at widely separated stations.

2. The telautograph, widely used in automobile assembly plants, transmits written orders from a central point to a large number of receiving stations.

3. The temporator, an electromechanical dialing device, serves for two-way communication through visible and audible annunciators.

These and similar instruments typify the progress being made in the development of better information-transmission systems. At the same time, the introduction of concepts such as "participation" indicates the headway being made to secure better communicators with greater capacity and more willingness to exchange needed information. These significant modifications in both the mechanical and human components of communication follow from the recognition that the person at the focal point in a communications system invariably is, or soon becomes, the effective leader or administrator.

In a smoothly functioning organization the important information channels converge at the top manager's position. This rule is sometimes violated, with the result that the bypassed administrator is soon relegated to a perfunctory role. Effective control of that organization is then assumed by those who have control of that organization's communications system. Obviously, this control refers to more than the mechanical handling of messages. This conclusion logically follows from the very nature of effective control. Such control requires both a knowledge of all pertinent data and the ability to transmit the necessary directives. Particularly in dynamic situations where the variable factors are numerous, complex, and constantly in flux, there must be an immediate and unimpeded nexus between the decision maker and the members of the organization.

COROLLARY 4. Motivation and Morale

Management might be termed a catalytic agent requisite to the extraction of effort from individuals in the process of achieving organizational objectives. Management acts as a catalyst when it engenders confidence, faith, zeal, and similar attitudes within the group members, making them more amenable to cooperative venture. Reference is made to management as a catalytic agent in so far as the basic impulses which propel individuals toward group activity cannot be created by the organization's leaders. Since these impelling forces are

very difficult to segregate, to identify, and to measure, there is no unanimity among authorities as to which are most important. Probably the 10 most commonly mentioned universal wants are the tendencies toward or the desires for (1) association, (2) acquisition, (3) approbation, (4) a sense of accomplishment, (5) love and loyalty, (6) dominance, (7) bodily integrity, (8) morality, (9) creativeness, and (10) curiosity. These 10 universal wants are not set forth in a sequence of importance, nor are they always consciously recognized as the motivating factors. Frequently they even lead to conflict, the resolution of which leads to compromise or conquest, with resultant deleterious effects.

Motivation generally implies any emotion or desire which so conditions one's will that the individual is propelled into action. Recognizing the almost infinite heterogeneity in humanity, it seems like a hopeless task to attempt any segregation of a single motivating factor as being of prime importance in attaining effective organization. Even more complex would be the measuring of the relative importance of several motivating forces.

Motivation is of prime importance to successful organization in so far as it is presumed that effective motivation leads to sound morale and thence to improved performance. Morale might be defined as the prevailing mood or spirit which is conducive to willing and dependable performance of tasks requisite to the attainment of organizational objectives. This mood is in large measure the product of the degree of faith in the cause, the leadership, and the ultimate success of group effort. Morale presumably determines the extent of cooperation in the common endeavor, leading, in exceptional cases, to zeal, self-sacrifice, or indomitableness. It should be emphasized that good morale is not necessarily synonymous with elation, cheerfulness, or what is sometimes termed good-fellowship. Good morale means much more than being in a good mood. Complacency, mediocrity, staticism, and even a fatalistic resignation must not be mistaken for good morale. Nor are extreme emotionalism, exuberance, dreamy ecstasy, wishful thinking, or similar states of suspended animation indicative of morale.

Because morale is a mental condition, almost insurmountable difficulties have been encountered by researchers striving to develop adequate measuring criteria. The best gauges that have been proposed to date are variants of indirect morale measurement through comprehensive studies of group and individual attitudes. Interviewing techniques, opinion polls, statistical analyses, and subjective appraisals are frequently used to estimate the relative level of morale prevailing in a given group.

As considered in this section, both morale and motivation are intimately related to value systems. Value, since it pertains to the satisfaction of needs or desires, originates with some basic urge. The intensity of these urges, the physical and psychological make-up of individuals, the measure of success in attaining objectives, and the ultimate degree of satisfaction derived from the group venture are among the most important variable factors in respect to morale and motivation. Generally, although there can be exceptions, a strongly motivated group will tend to be cooperative, loyal to the organization, resolute in purpose, dynamic, resourceful, and well disciplined.

COROLLARY 5. Personification of the Organization

Considered solely from its structural aspects, an organization is an inanimate being. However, since by definition an organization is a grouping of individuals with kindred objectives, it is inevitable that organizations assume certain aspects of animation. In a sense, every organization acquires a distinct personality. As with human beings, so too with the organization, this personality is the result of environmental factors and transmitted traits. The latter determinant might, by analogy, be termed heredity. The inherited characteristics depend largely upon the type of individual who first assumes control. As a rule, the dominant executive selects as his immediate associates individuals with relatively similar backgrounds, personalities, and aspirations. This process of selection practically assures a continuity comparable to that resulting from heredity.

Environmental forces likewise exert an influence in the molding of an organization's personality. This influence consists in the application of considerable pressure upon the individual to conform to specific behavior patterns. For example, standard-practice instructions regulate the performance of duties inherent in the various positions. Daily contact with company policies and with specific individuals acts as a conditioner. Members of the group who deviate considerably from the accepted patterns soon find themselves marked as organizational outcasts. Eventually this pressure to conform tends to yield relative homogeneity within given groups.

Environmental pressure also affects the composite organizational personality. Modifications in the public attitude toward issues such as unionization, competition, corporate taxation, and the like, cannot successfully be ignored by individual industrial organizations. This pressure to conform has been the greatest single civilizing force in replacing the robber-baron type of entrepreneur by the modern public-conscious, college-trained, professional industrial manager. An organi-

zation that attempts resisting environmental pressures soon finds itself labeled as suspect. In the business sphere such reaction invariably has a negative effect upon the concern's competitive position. As Charles Darwin demonstrated in his study *Origin of Species,* evolutionary adaptation to changing circumstance is absolutely imperative for survival of all living things, from the lowest to the highest order. Paleontology provides countless examples of living organisms, such as the dodo and the dinosaur, which became extinct because of their failure to adapt to changes in environment. A comparison of today's hundred largest corporations and the one hundred largest companies a half century ago would indicate that more than one-third of these latter concerns no longer rank among the top hundred. A few of the companies, such as American Woolen and United States Leather, have actually disappeared as independent entities.

Although external forces are constantly acting upon the organization and comparable internal forces pressure the individual members of the group, there is nevertheless a tendency to maintain the *status quo.* This tendency, in a sense, is an equilibrator. An organization's personality, once it is fixed, is just as difficult to modify as are the habits of individuals.

The inevitable consequence of environmental and hereditary factors is the succession of individuals with similar traits and attributes in the organizational chain of command. This is amply manifest in corporate promotional policies and, even at the highest level, in the selection of directors and top executives specifically by means of the proxy system.

The process by which organizations are said to acquire personalities goes even further to the point where these legally or socially sanctioned imaginary beings are presumed to act as humans. Thus corporations can own property, deal with unions, make contracts, etc. This hypothetical assumption of a three-dimensional substance by organizations can be termed reification, or quantification. It is this process which makes possible the performance of actions requisite to an organization's attainment of its objectives. For example, corporations could not otherwise do business under a money economy.

Personification of organizations has some very significant ramifications. The group members tend to submerge their own personalities and to assume the traits and attributes of the organization to which they belong. The effectiveness of these transmutations can be inferred from the intensity of morale permeating the organization. The highest form of morale results from the frictionless identification of individual personalities with that of the organization. This oneness of personality

provides a unity of purpose which facilitates organizational operation. In a sense, then, morale is a concomitant of unanimity of group and individual purpose.

Where significant discrepancies are found between the organization's personality and the personalities of its members, performance tends to be negatively affected. If a sizable portion of the group's members have traits and aspirations different from the organization's, not only is morale lowered and performance reduced but the very character of the organization becomes subject to radical modification.

This analogy of an organization assuming human characteristics illustrates the importance of proper staffing of organization structures. The consequences are obvious. It is vital, therefore, if conflict between group and individual personalities is to be minimized, that consideration be given to:

1. Judicious selection of personnel
2. Proper training as to the ideals and tenets of the organization
3. A comprehension of mutuality of group and individual aspirations
4. Equitable treatment for all members
5. Modification of the organization's personality when internal or external pressures so warrant

SIGNIFICANCE

From the foregoing it would appear that the attitudes of individuals condition to a great degree what might be termed group philosophies, group behavior, and group objectives. Consequently, a comprehension of subjects, such as motivation, morale, integration, participation, and the like, should presumably be beneficial to one who seeks to maximize the effectiveness of group ventures. Every leader, from general to corporal, from president to foreman, could attain loftier aspirations and with greater facility, through better understanding of what his associates want and to what extent they are willing to expend effort to satisfy these wants.

The human factors are important not only because they condition organizational effectiveness but also because they tend to make changes mandatory in organization structure. This would explain in part the shift from the one-man, highly centralized type of control predominant a half century ago in American industry to the relatively decentralized committee- or group-controlled organization currently in vogue, particularly in large-scale enterprise. It is generally assumed that such a transition is simply the result of growth in scale of operation. Rather recently some students of management philosophy have evidenced

their concern for the structural modifications, necessitated by what might be termed sociological and psychological considerations. An outstanding contribution has been made in this respect by William H. Whyte, Jr. In numerous *Fortune* articles, and specifically in his very interesting book *The Organization Man,* Whyte points to the possibility that groupthink, human engineering, multiple management, and similar popular notions manifest much more than the simple desire of the worker for recognition and participation in corporate affairs. Whyte's thesis is built upon the premise that the competitive spirit which characterized the building of our nation and our economy is rapidly giving way to a debilitating reliance upon group decisions. He refers to the use of a device called a Group-Thinkometer, by means of which the members of a committee can pool their judgment simply by pressing concealed buttons to record their individual choices. This device is simply a glamorized version of the secret ballot and of the more ancient technique of "ostracism," that is, voting by means of different-colored balls or shells. In an organization of equals, there is no room for individual genius or even for talent. The predominance of the group and the subordination of the individual brings to mind the age-old controversy, discussed in the previous chapter, relative to the antithetical premises accepted by Plato and Aristotle as to the primacy of the individual or of the group. If the view, currently so dogmatically propounded by many sociologists and social psychologists, that the prime desires of human beings are for security and belongingness is correct, then there might be some justification for participation, groupthink, adjustment, and the rash of similar quasi-scientific fads.

On the other hand, as is pointed out in corollary 1, the current emphasis on the primacy of the group is probably a reaction to the remarkably successful philosophy of organization stressing the importance of individual differences. The necessity of appealing to large numbers of individuals, among whom there is a heterogeneity of interests and of attributes, has necessitated the acceptance of a value system which would appeal to the greatest number of individuals. Thus monetary standards, materialism, and the economic-man concept have almost inextricably been meshed with criteria of success. Inequities in rewards, together with a natural revulsion to the adulation of the dollar and the subordination of loftier ideals, purportedly have given impetus to the belief that the group rather than the individual should perform the functions of decision making and control in modern industry.

Such a fraudulent philosophy bears watching. It caters to the idealist

seeking to build a better world through the brotherhood of man. However, it also appeals to mediocrity, to slothfulness, and to inertia. History is replete with examples of great leaders who reached eminence not alone through an eminent capacity, chance, or catering to the whims of the group, but also through the extreme application of effort in the utilization of capacity. Napoleon's comment, "Work is my element. I am born and built for work. I have known the limitations of my legs, I have known the limitations of my eyes; I have never been able to know the limitations of my working capacity," [5] is typical. It would seem that underlying the disparaging of individual eminence and the glorifying of groupthink is the Lilliputian hope that by shackling Gulliver the little men will have everlasting peace and prosperity.

ILLUSTRATION 1. The Bridge of Fayol

The hierarchy is the series of officials which runs in order of rank from the supreme authority to the lowest employee. The hierarchic channel is the road which all communications leaving or addressed to the supreme authority follow in passing through all the ranks of the hierarchy. The need for this channel arises both from the need for safe transmission and from unity of command but it is not always the quickest channel, and in very big enterprises, the State in particular, it is sometimes disastrously long. As, however, there are many operations whose success depends on rapid execution, we must find a means of reconciling respect for the hierarchic channel with the need for quick action. This can be done in the following way:

Let us suppose that it is necessary to put function F in communication with function P, in an undertaking whose hierarchy is represented by the double ladder G–A–Q. In order to follow the hierarchic channel, we should have to climb the ladder from F to A and then go down from A to P, stopping at each rung, and then repeat this journey in the opposite direction in order to get back to our starting point.

```
         A
        B L
       C   M
      D     N
     E       O
    F- - - - -P
   G           Q
```

It is clearly much simpler and quicker to go straight from F to P by using the "bridge" F–P, and this is what is most frequently done. The hierarchic principle will be safeguarded if E and O have authorized their respective sub-

[5] J. Christopher Herold, *The Mind of Napoleon,* Columbia University Press, New York, 1955, pp. xx–xxi.

ordinates, F and P, to enter into direct relations, and the situation will, finally, be perfectly in order if F and P immediately tell their respective chiefs what they have agreed to do. So long as F and P remain in agreement and their actions are approved by their immediate supervisors, direct relations can be continued, but as soon as either of these conditions ceases to exist, direct relations must stop and the hierarchic channel be resumed.[6]

QUESTIONS

1. What additional safeguards should be taken to ensure effective communications and to preserve management's prerogatives?
2. Would this "bridge" apply equally to "flat"-type and pyramidal organization structures?
3. What type of communications would presumably be unaffected by this short-cutting?

ILLUSTRATION 2. Sears, Roebuck

Perhaps the most graphic—and significant—demonstration of the structure's force cropped up in the course of a routine morale survey Sears, Roebuck made of its retail stores in 1949. For years the stores had been organized along either of two lines: (1) a relatively centralized pyramidal structure; (2) a "flat" type that put great emphasis on delegation of authority. Otherwise, they were pretty much alike. But when the time came to make a breakdown of findings of the survey, Sears' personnel department found that the chart was shaping up in a surprising way. With few exceptions, the stores whose morale standing placed them at the top of the chart were the "flat" type; the stores at the bottom, the pyramidal type. Their curiosity aroused, the personnel people went on to make a check of where most of the "promotables" were coming from. Answer: the "flat" stores.

Significantly, Sears also found that it would be unwise to charge ahead and convert everybody to the "flat" structure. "The executives that the pyramid had—in effect—selected," says Sears' Jim Worthy, "would have had a rough time functioning well in a looser setup. To change the structure, you have to change the guys." [7]

QUESTIONS

1. What factors might lead you to believe that Sears, Roebuck's experience might not be typical for most United States industry?
2. What are the disadvantages of the flat version of organization structure?
3. Show arithmetically the difference in the number of personnel that can be supervised in a three-layer flat organization as compared with a five-level pyramid structure.
4. Early in 1957 the Kroger Company reorganized its chain of 1,475 food stores,

[6] Henri Fayol, "The Hierarchy," *Industrial and General Administration,* translated from the French by J. A. Courbrough, International Management Institute, Geneva, pp. 28–29.

[7] "Problem of the Front Office," *Fortune,* May, 1951, pp. 148–151.

designating its 24 branch managers as divisional vice-presidents. Each unit, consisting of a distribution center and a ring of stores, was given considerable autonomy. What advantages, from a staffing point of view, might Kroger Company be seeking in addition to those claimed by Sears, Roebuck for its comparable flat structure?

ILLUSTRATION 3. Human Engineering

There is a whole vast area in which we are only beginning to make significant progress—what we might call the field of human engineering. Machines alone do not give us mass production. Mass production is achieved by both machines and men. And while we have gone a very long way toward perfecting our mechanical operations we have not successfully written into our equations whatever complex factor represents *man,* the human element. I am suggesting, therefore, that we try to rewrite the equations to take into account the human factor. If we can solve the problem of human relations in industrial production, I believe we can make as much progress toward lower costs during the next ten years as we made during the past quarter century through the development of the machinery of mass production.[8]

QUESTIONS

1. Do you feel that "human engineering" meant the same to Henry Ford as it does to those who currently use the term?
2. Is there any indication that Ford's prediction in the last sentence of this excerpt has been achieved?
3. What might human engineering mean in a socialistic planned economy?

ILLUSTRATION 4. "Executive Suite" [9]

". . . We have an obligation to our stockholders—but it's a bigger obligation than just paying dividends. We have to keep this company *alive.* That's the important thing—and a company is like a man. No man can work for money alone. It isn't enough. You starve his soul when you try it—and you can starve a company to death in the same way. Yes, I know—sometimes our men in the factories give us the impression that all they want is another raise in wages—and then another and another and another. They make us think that getting more money is all that matters to them. But can we blame them for that? God knows, we've done our best to try to make them believe that money is the only measure of accomplishment that matters to us.

"Look at what we did this last year with what we called a 'communications program.' We put out a movie that analyzed our financial report and had meetings in all the plants. The men weren't much interested in our financial report—we knew that to begin with, it was the premise we started from—so what did we do? We tried to *force* them into being interested. We disguised the dollars as cartoons—little cartoon dollars that jumped into workers' pock-

[8] Henry Ford, "Challenge of Human Engineering," *Advanced Management,* vol. 11, June, 1946, pp. 48–51.

[9] Cameron Hawley, *Executive Suite,* Houghton Mifflin Company, Boston, 1952, pp. 333–335.

etbooks—other little cartoon dollars that dragged in piles of lumber and built factories—and a big fat dollar that took a trip to Washington and was gobbled up by Uncle Sam. Oh, it was all very clever—even won some kind of an award as an outstanding example of how to promote industrial understanding. Understanding? Do you know what it forced our men to understand? Only one thing—the terrible, soul-killing fact that dollars were all that mattered to the management of this company—dollars—dollars—and nothing else. . . .

". . . You see, to Mr. Bullard, business was a game—a very serious game, but still a game—the way war is a game to a soldier. He was never much concerned about money for its own sake. I remember his saying once that dollars were just a way of keeping score. I don't think he was too much concerned about personal power, either—just power for power's sake. I know that's the easy way to explain the drive that any great man has—the lust for power—but I don't think that was true of Avery Bullard. The thing that kept him going was his terrific pride in himself—the driving urge to do things that no other man on earth could do. . . .

"There was one thing that Avery Bullard never understood. . . . He never realized that other men had to be proud, too—that the force behind a great company had to be more than the pride of one man—that it had to be the pride of thousands of men. A company is like an army—it fights on its pride. You can't win wars with paychecks. In all the history of the world there's never been a great army of mercenaries. You can't pay a man enough to make him lay down his life. He wants more than money. Maybe Avery Bullard knew that once—maybe he'd just forgotten it—but that's where he made his mistake. He was a little lost these last few years. He'd won his fight to build a great company. The building was over—at least for the time being. There had to be something else to satisfy his pride—bigger sales—more profit—something."

QUESTIONS

1. Do you agree with the principles for effective group action enunciated in these excerpts?
2. Could Mr. Bullard be considered typical of modern businessmen in respect to the traits mentioned?
3. Assuming that Mr. Bullard's communications program had serious limitations, what substitute program would you suggest?
4. Discounting monetary rewards, what motivating factors do you think impel you to the maximizing of your own power and capacity factors?

ILLUSTRATION 5. Caterpillars

Processionary caterpillars feed upon pine needles; they move through the trees in a long procession, one leading and the others following—each with his eyes half closed and head snugly fitted against the rear extremity of his predecessor.

Jean-Henri Fabre, the great French naturalist, after patiently experimenting with a group of these caterpillars, enticed them to the rim of a large

flower pot where he succeeded in getting the first one connected up with the last one, thus forming a complete circle which started moving around in a procession which had neither beginning nor end.

The naturalist expected that after a while they would catch on to the joke —get tired of their useless march and start off in some new direction, but not so. Through sheer force of habit the living, creeping circle kept moving around the rim of the pot, around and around, keeping the same relentless pace for seven days and seven nights—and would doubtless have continued longer, had it not been for sheer exhaustion and ultimate starvation. Incidentally, an ample supply of food was close at hand and plainly visible, but it was outside the range of the circle so they continued along the beaten path.

They were following instinct—habit—custom—tradition—precedent—past experience—or whatever you may choose to call it, but they were following it blindly. They mistook activity for accomplishment, they meant well, but they got no place.[10]

QUESTIONS

1. Do you agree with the very obvious moral expressed in this excerpt?
2. How can such blind "followership" be counteracted?
3. Is devotion to discipline an inherited trait or an acquired characteristic?
4. To what extent is such discipline necessary for effective organization?

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CHAPTER 7

Decision Making

DEFINITION AND DESCRIPTION

The most vital ingredients in the managerial process have been listed as (1) deciding on a course of action, (2) obtaining the necessary physical means, (3) convincing others to assist in the performance of requisite tasks, (4) seeing that the job is properly accomplished, and then (5) apportioning the product of the joint venture. Even cursory study reveals that decision making is fundamental to each of these managerial functions. In particular, items 1 and 3 rest heavily on subjective appraisal and sound judgment. The remaining three functions, although integral to decision making, are actually components of decision implementation. In this respect items 2, 4, and 5 are largely concerned with the application of managerial techniques.

Decision making can be defined as that thinking process which leads logically to the recognition of specific wants and thence to the determination to attain these wants by use of selected means. The actual use of the selected means is the characteristic differentiating decision making from decision implementation. The first phase, decision making strictly so called, consists of the following steps:

1. Perception. A state of awareness, generally sensory in character, out of which a consciousness of being arises.

2. Conception. That power of the mind which develops ideas out of perceptions. Concepts might be termed schemes or designs for action.

3. Investigation. The search for and the acquisition of information

pertinent to specific concepts so that the relative advantages and limitations of alternative courses of action can be compared.

4. *Deliberation.* A mental weighing of relative merits and consequences attached to alternative schemes of action.

5. *Selection.* A discrimination among the available alternatives so that the most desirable course of action is designated as *the decision.*

6. *Promulgation.* A declaration or public pronouncement of the decision so that all persons concerned are adequately notified. This act of notifying all interested persons can also be considered as an aspect of communication.

The next three steps, although intimately connected with decision making, should be more properly differentiated as forming the decision-implementation process.

7. *Actuation.* The application of effort, mental and physical, to the fulfillment of the prescriptions encompassed within the selected course of action. Actuation is an energizing process putting decisions into motion.

8. *Supervision.* The exercising of direction and control to the degree that specific instructions prescribed for the selected course of action are satisfactorily carried out.

9. *Adjudication.* An evaluation of accomplishment as compared with the objectives. In a sense this is a judicial process since the individual vested with the authority and responsibility pertinent to the success of the decision must ultimately act as a judge of its success or failure.

It can be inferred from the foregoing that the process of making decisions and carrying them to fruition is essentially a rational procedure consisting of volition, judgment, communication, and control. This chapter will be dedicated to the first two aspects, volition and judgment. The subject of communication has already been broached in Chapter 6. The topic of control is given relatively intensive study in Chapter 9.

Volition within an organization is, obviously, a composite of the hopes and desires of all the individuals comprising that group. The tangible expression of organizational volition is the objective of the enterprise, defined, in a general way, in the corporate charter or some similar document and, more specifically, in company policies, plans, and procedures. In turn, these expressions of group desire, and the effectiveness with which they are expressed and accomplished, depend largely upon the prevailing value system and the caliber and zeal of the organization's leadership. The value system reflects the ethical, economic, professional, and philosophical composite of the organization. The wants, desires, aspirations, objectives, goals, etc., associated

with the specific value system must be reasonably attainable. Rationalization or wishful thinking should not be confused with the reasoning process associated with the attainment of economic wants.

Sound judgment is equally important to effective decision making. The intensity of desires, the probability of attaining selected goals, and the degree of satisfaction resulting from such attainment should provide the basis for rendering judgments. The ability to compare and to judge alternatives requires a high level of technical competency. Lacking such competency, a manager is unable to comprehend the advantages and the limitations of the several available courses of action. It is this emphasis on adequate technical grooming for sound judgment in rendering decisions which makes mandatory education in business administration. Despite the protestations from certain quarters that a broad, general background is sufficient for entrance into and advancement within the sphere of business, no substitute has as yet been devised for sound judgment based on technical competency. Proponents of the broad background are correct when they contend that much more than an acquaintance with techniques and procedures is necessary for effective management. They are absolutely incorrect if they assume that common sense or the ability to think are alone sufficient to run an enterprise. Such specious reasoning is patently ridiculous whether the area in question is business administration, medicine, law, engineering, or any comparable profession.

Nexus in Decision Making. No decision is self-generated. The desires which initiate a new decision-making process are invariably the products of decisions made in the past. While these wants can increase or diminish in intensity, they are much like the mythical phoenix which, after living for five hundred years and then being consumed in fire by its own act, would rise in youthful freshness from its ashes. Thus, in a sense, decision making functions in the fashion of a cycle, entailing an extension of the past, through the present, and into the future. An excellent clarification of this concept of the interrelationship of decisions is presented in the Hegelian terminology of thesis, synthesis, and antithesis. The first phase, thesis, is an affirmation which is equivalent to a specific decision. This definitive statement does not go unchallenged indefinitely. In fact, it is presumed to contain within itself a contradiction which leads eventually to modification or even to destruction of the thesis. This contradiction is termed the antithesis. Fortunately, the human mind does not stop with contradiction but immediately strives to reconcile thesis and antithesis. This harmonizing force or principle is known as synthesis. Out of this synthesis, which is not to be confused with compromise, the values of

both thesis and antithesis are conserved and new values are created. In somewhat a similar "dialectical process" there is generally a counterforce (antithesis) to an accepted decision (thesis) which necessitates reappraisal and a new decision (synthesis). The original thesis and the subsequent antithesis do not disappear entirely. Their interaction, in addition to initiating the genesis of a new decision, unifies the better aspects or values of both the original decision and its challenger.

Locus of Decision Making. It is a gross misconception to assume that decision making is strictly a top-level administrative function. On the contrary, every member of an organization must, rather regularly, perform tasks which require a choice as to what is to be done and how, when, and where the action is to take place. This leads to a precept of effective management, namely, that all decisions should be made at the lowest organizational level commensurate with the qualifications of the individuals, the nature of the problem, and the degree of authority and responsibility vested in the particular position. A proper differentiation of the importance of the decision to be rendered is vital in so far as modern management presumably functions on the exception principle. This exception principle simply states that routine matters should be allocated to an individual competent and authorized to deal with such occurrences. When a deviation from the routine occurs, the matter should be relayed to a specific position or a managerial level which is qualified to deal with the exceptional problem. If the exception principle is properly practiced, then simple operative tasks and problems are resolved at the working level by the workers and their foremen. On the other hand, decisions relative to the basic objectives of the organization and its broad plans and policies are reserved for the top executives. Although the exception principle has considerable economic value and is imperative for sound organization, there is no rigid general formula by which certain types of problems are shunted into a given administrative level for solution. Every organization must custom-build its structure, designating certain decision-making duties for each level of authority and for each position. As a consequence of hazy definition, neglect, usurpation, and custom, there is frequently an overlapping as to the decision-making function. The consequences of such overlapping are invariably "buck passing" and indecision.

The terms *philosophy, policy, plan, procedure, project, practice,* and *precedent,* used in Chapter 3 to designate various levels of performance standards, might likewise be used to stress the varying importance of decision making by hierarchical levels. In Exhibit 7-1 there is a downward progression of importance in the vertical column

from stockholder to worker and a diminishing importance moving horizontally from philosophy to project. The overlapping, as, for example, in the policy category where four hierarchical levels participate, indicates the relative impossibility of establishing accurate lines of demarcation. From this it can be inferred that each of the hierarchical levels is concerned with more than a single type or degree of decision making. Top executives, for example, must assist in determining the corporate philosophy, its policies, plans, and procedures. In some instances the executive's functions are even more extensive. The portion of time and the intensity of effort allocated to each of these

Exhibit 7-1. Allocation of Decision-making Functions

	Philosophy	Policy	Plan	Procedure	Project
Stockholders	xxxxx	xx			
Board of directors	xxx	xxxx	xx		
Executives	x	xxxx	xxxxx	x	
Middle management		xx	xxxx	xxxx	
Foremen			x	xxxxx	xx
Workers				xxx	xxxx

spheres vary so greatly that even an estimate would not be warranted. Exhibit 7-1 is included simply to illustrate a concept. It is not an attempt at precise measurement.

Process of Policy Formulation. A policy has been defined as a general statement of the action to be taken relative to a basic tenet of the organization's philosophy. Policies have been likened to broad channels which help guide the efforts of the group toward the desired objectives. The most fundamental of these objectives is generally spelled out in the purpose clause of the organization's charter. These basic aspirations are, however, expressed in such general terms that additional written statements of the more immediate objectives and the pertinent means and manner of attainment are necessary. In this connection a great variety of company "creeds," statements of purpose, enumeration of goals, and detailed policies in manual form are published by the leading industrial enterprises. In addition to such written policies, there are numerous oral and implied policies. The limitations of unwritten policies, and specifically their ambiguity and remoteness, should be apparent.

While policies refer to the attainment of corporate objectives and are primarily the prerogative and responsibility of the stockholders, all members of the industrial organization help in the formulation process. This follows from the realization that policies which cannot

be applied are meaningless. Similarly, policies are the product of exigency, arising only when company operations and procedures manifest the need for a specific declaration of objective. Consequently, it might be said that policy formulation initiates at the lowest operating levels of the enterprise.

The precise steps followed in policy formulation cannot be categorically spelled out since company needs, resources, environment, and philosophies vary so widely. For those who require a sequential procedure, the nine steps in decision making listed at the beginning of this chapter might serve as a guide. Another clarification of policy development, although it does not list the specific steps in the formulation of a given policy, is proposed by Jamison. "First, an ideal is an unexpressed vision; second, a purpose is a vision reduced to a studied attempt to realize the ideal; third, an objective is a goal selected as the best way to satisfy the purpose; and fourth, a policy is an objective expressed in a definite statement." [1] It must be remembered, however, that the great diversity in corporate structures, functions, objectives, and philosophies necessarily means heterogeneity in both corporate policies and in the processes of policy formulation. Despite this heterogeneity every industrial organization must provide for itself some systematic process of establishing policies, arranging them in a sequence of priority, providing for periodic reappraisal, and when necessary, terminating policies no longer useful to the enterprise. This approach is essential since an organization's structure is vitalized by the policies in force. The ultimate test of the effectiveness of an enterprise's policies is the satisfaction experienced by the group and the continued recognition that the policy is necessary.

The Process of Planning. A plan has been defined in Chapter 3 as a detailed course of action by means of which policies are activated and implemented. The planning process proper consists of the first five of the nine decision-making steps listed earlier. Perception and conception lead to the psychological impulses of wanting or desiring. All business plans are concerned with the satisfaction of these wants or desires. Since human wants are relatively infinite and are found in every imaginable intensity, proportion, and variation, there evidently is great disparity and even conflict to be found among plans. The next three decision-making steps, investigation, deliberation, and selection, comprise the judgment process by which all pertinent elements are considered and the most desirable alternative is chosen.

Stated nontechnically, a plan is simply a decision to undertake a

[1] Charles L. Jamison, *Business Policy*, Prentice-Hall, Inc., Englewood Cliffs, N.J., 1953, p. 8.

particular activity involving the expenditure of effort. Plans of individuals, as well as of organizations, industrial or otherwise, must possess at least the following characteristics: (1) objectivity, (2) futurity, (3) logical structure, (4) acceptability, and (5) flexibility.

It has been postulated that the basic objective of all industrial enterprise is the creation and distribution of utility. This basic objective would be quite elusive unless measures were taken to convert the broad goal into practical and present actions and attainments. Gauged on a temporal basis, ultimate objectives must be converted into more specific intermediate objectives and then into even more tangible terms which might be labeled immediate objectives.

Closely allied with objectivity is the topic of futurity. All planning is anticipation. It must be remembered, however, that anticipation without a basis in fact is wishful thinking. "Waiting for one's ship to come in" is typical of a form of anticipation which is illusion rather than planning. Unfortunately, this illusory type of anticipation is extremely common, complicating the analysis of sound planning and decision making. Since futurity implies the presence of unknown elements, there is always a measure of speculation inherent in planning. The effectiveness of planning is closely related to the degree that all known factors can be kept within reasonable tolerances while unknown factors are kept at a minimum. It is also imperative that reasonable estimates be made as to the probable effects of the unknown elements.

From the foregoing, it is apparent that a good plan, in addition to objectivity and futurity, must be logical. By its very nature, planning is a prerogative of rational beings. Violations of the rules of logic result in plans which are either unattainable, weak, or even harmful. The importance of basing plans upon facts wherever possible and upon sound value judgments when facts are unavailable cannot be overemphasized. While the nature of this text does not permit a more elaborate treatment, it is hoped that the specific discussion of logic in corollary 1 and the less detailed references throughout the text will help awaken the student's interest in this vital prerequisite.

Despite the need, soundness, purpose, and reasonableness of a plan, its effectiveness depends upon the degree to which interested individuals accept the plan, its connotations and ramifications. Acceptance implies willingness to cooperate to the fullest. Acceptance with reservation or reluctance decreases the potential effectiveness of a decision. Thus acceptance of all pertinent decisions, including plans, is vital to organizational motivation and morale, whose importance has already been emphasized.

Finally, a good decision must possess flexibility. No organization, considered from either its structural or personnel aspects, is so rigid and immutable that it can be termed eternally constant. Changes within an organization demand that its components possess a facility in adaptation. External forces, likewise, and in an even greater intensity, necessitate modification. Consequently, every plan should be so constituted that when circumstances warrant, the course of action will be altered. Such a plan has flexibility.

These five aspects, objectivity, futurity, logical structure, acceptability, and flexibility, are basic attributes requisite to sound planning and to sound decision making. While they do not outline a precise process of planning, close adherence to these attributes will facilitate the process. To propose more than these broad guides would involve conjecture, meaningless incidentals, and an exhaustive treatise on the art of rational behavior.

DEVELOPMENT

The first decision was probably rendered soon after man acquired the power of judgment. The universality and antiquity of the concept of decision making require for even a very general consideration of its development far more space than can be devoted to it in this type of text. Consequently, this section will deal with only a single phase of the more recent development of this concept—specifically with the growing importance of group decisions.

The separation of business ownership and control has complicated the decision-making process in the sphere of industry. Those actively in charge of corporate affairs must be adequately motivated to maximize their leadership abilities. As will be described in Chapter 9, most of our large industrial organizations are run by executives who cannot claim the residual returns, or profits, of ownership. One of the most perplexing problems of modern industrial management is concerned with the question as to how hired managers can be induced to exert themselves mentally to the maximum in performing decision-making functions formerly considered the sole prerogative of the owners. Then too, as industrial technology becomes more complex and as scale of enterprise reaches Gargantuan proportions, it becomes progressively more difficult to find qualified top-level decision makers. This becomes even more serious when capable individuals hesitate assuming such responsibilities for a variety of reasons.

The growing need for and the relative dearth of qualified decision makers have brought about interesting innovations. It is believed by some that if individual decision makers are unavailable, then by a

process of synthesis, a composite of requisite attributes residing in a number of different individuals can be combined to produce a group decision maker. The basic idea underlying this concept is, obviously, not new. Its application to industrial organization, however, is a recent phenomenon. This group approach has numerous manifestations, among which is the increased incidence of committees, the greater reliance on attitude surveys, opinion polls, motivation research, and the popularity of a wide variety of fads which fall within the category of groupthink.

Outstanding among these groupthink techniques is brainstorming, the creation of Alex F. Osborn, cofounder of the New York advertising firm of Batten, Barton, Durstine, and Osborn. In essence the technique is somewhat of an open forum on one specific problem affecting a given company. Proponents prefer to label the technique "creative thinking." They claim it yields much better results as compared with the haggling, compromising, and stalemating of the typical conference session. A premise upon which brainstorming rests is the belief that the creative mind does not work in an orderly fashion. Ideas are presumably gestated in a haphazard fashion and generally need some sort of external stimulation. The objective of brainstorming, then, is to get a group of 8 to 12 competent, responsible, and interested individuals to state their thoughts concerning a common problem or situation. After a brief introductory "warm-up" period, the ideas begin to come forth, sometimes with amazing rapidity. For example, at one creative-thinking conference, brainstorming brought forth 45 ideas in less than six minutes. In the typical one-hour session, a hundred or more ideas are generally forthcoming. Obviously, this high incidence of ideas is no indicator as to their quality. Consequently, a severe culling operation follows the initial session whereby the mass of ideas is reduced to a few which seem practical. These selected ideas are then presented to the proper executives for consideration.

The popularity of brainstorming has resulted in the development of a rather formalized procedure in its application. Numerous articles and books on the subject have helped crystallize procedure and provide what might be called a semitechnical vocabulary.

This brief discussion of one of the most popular groupthink techniques has been ventured because of its serious connotations for decision making. Truly creative thinking has been, for a long time, considered to be the product of individual effort. Decision making likewise, and particularly in the sphere of industrial administration, has been associated with the individual. Although decision makers

have from time immemorial used the services of advisors, in staff capacities or otherwise, the decision finally rendered has always been the responsibility of the individual executive. If through groupthink in general, or brainstorming in particular, the individual is replaced by the group as the fountainhead of creative thought, then a significant transformation will have been effected. Practically all the concepts of industrial management, and especially the concepts of organization dynamics and decision making, would need drastic reappraisal. On the other hand, brainstorming and related practices might simply reflect administrative desperation. Recognizing the extreme scarcity of that strategic factor, creative thinking, administrators might simply be grasping at even the semblance of a substitute.

Among the prime objections to brainstorming are the following:

1. It tends to raise questions as to the value of staff specialists who presumably should be competent to perform their assigned functions.
2. There is a danger in exaggerating the importance of the frequency and incidence of ideas.
3. The technique leans heavily on the executive who must cull the sound ideas from the impractical and facetious comments.
4. The participants can easily get a false notion of their technical competency.
5. The method has all the disadvantages associated with committees and conferences.
6. There is an absence of association of idea and contributor and, presumably, no specific and proportionate compensation.
7. Brainstorming seems to be merely another version of the suggestion system, possessing all its limitations.

The relative newness of group decision-making techniques makes evaluation rather tenuous. If a pooling of ideas serves to maximize the creative-thinking process, the managerial function of decision making is undoubtedly fulfilled more effectively. Conversely, such action can be interpreted as a desperate maneuver by insecure and, perhaps, incompetent administrators to get their subordinates to assume the administrator's responsibilities. Such subterfuge would obviously be reprehensible. An even more ominous thought follows from the inference that groupthink and related techniques are manifestations of a major social upheaval wherein the individual is being subordinated in all respects to the group. The implications of such a shift are serious not only for decision making but for all aspects of organization. Some reference has been made in Chapter 5 to the continuing debate as to the primacy of the individual or the state. A reversal in belief would have drastic consequences upon our socio-economic-po-

litical structure, which currently rests upon the dignity, importance, and capability of the individual.

COROLLARY 1. Principles of Logic and Decision Making

It has previously been stated that there is no substitute for technical competency in making sound decisions. This technical competency implies an intimate acquaintance with all the pertinent industrial characteristics, terminology, concepts, problems, etc. It also means that the decision maker has become well versed in applying the basic principles of logic. These principles are in many instances acquired by experience alone. The high cost of such trial-and-error learning is obvious. As the cost of making poor decisions becomes progressively higher, it becomes apparent that we cannot rely on chance for the acquisition, in the every day work environment, of the principles of logic. Therefore a vestibule training, preferably by a formal academic exposure, becomes almost mandatory.

It is absolutely impossible to compress a course in logic into a few summary paragraphs. Consequently, this presentation will be in the nature of a review of principles, on the assumption that the serious student has either had a course in logic or will soon endeavor a more intensive analysis.

Logic can be defined as the study of reasoning, that is, of the mental process by which we pass from premises to a proposition based on those premises. Since decision making has already been described as a reasoning process, it is obvious that the effective decision maker must also be a skilled logician. Basically, logic is synonymous with intelligent behavior. Our prime concern in this text is with intelligent behavior in respect to attainment of group objectives in the sphere of industry.

There are two major methods of reasoning: deduction and induction. Both are vital to decision making. In practice they are so inextricably intermingled that one cannot be said to be more important than the other. In fact, many of the basic assumptions used in the deductive process were at some time derived by means of the inductive method.

Deduction is that reasoning process by means of which pertinent information is acquired regarding a specific item or instance by relating it to certain basic assumptions or general principles. Propositions, called premises, are used as evidence or reasons. These premises are beliefs, ideas, customs, convictions, or assumptions considered to be truths by the person doing the reasoning. The decision reached in the deductive process is itself a new proposition technically termed

the conclusion. The mental process by which such conclusions are reached from the accepted premises is called inference. It should be kept in mind that if false premises are set forth, if a premise is misrepresented, or if a faulty inference is concluded, then the specific process of deduction is suspect. Deductive logic depends upon the degree of belief in the truth of the basic propositions. Decision making by this process is, obviously, limited by the credibility of the propositions. For example, if a specific standard or policy is considered inadequate, then the making of valid inferences using such a standard or policy as a premise is seriously limited.

The inductive process of reasoning might be viewed as the reverse of the deductive method. General principles or generalizations are ventured on the basis of evidence gathered from individual or sample instances. Such generalization provides a basis for decisions where individual verification of each item is impractical or impossible. In this method of generalizing, since all pertinent items cannot be adequately tested, reliance must be placed in the analysis of representative samples. Adherence to prescribed methodology in the selection and analysis of such samples is of vital importance. Some of the norms for proper sampling technique will be mentioned in subsequent chapters.

The process of induction, since it attempts to make assertions concerning all members or items within a class or group on the evidence relating to only a portion of that class or group, must be used with caution. Subjective appraisal frequently leads to rival hypotheses. The greater the incidence of such rival hypotheses, the lower is the probability regarding the validity of an individual hypothesis. Then too, the reliability of a hypothesis depends upon the character of the evidence upon which it is based. Paucity of relevant facts should cast suspicion upon the reasoning process since the probability that some relevant facts are missing is proportionately increased. Reliability, as used here, refers to the degree of confidence which we can place in a specific proposition. When we can take for granted that a proposition or inference is true, then we say it is reliable. Probability pertains to the degree of likelihood that, based on the evidence on hand, a proposition is true.

In every form of problem solving and decision making adequate consideration must be given to the consequences of alternative possibilities. Recognition of alternatives implies acquaintance with all pertinent facts, relationships, principles, and laws. Except in those relatively few instances where all the pertinent propositions are constants or rigidly controllable and measurable variables, sound judgment

is requisite for logical inference. Consequently, the technician replete with know-how need not necessarily be an effective decision maker. This is particularly the case if the reasoning process depends upon propositions only remotely concerned with his specific body of technical knowledge. Conversely, a skilled logician can prove to be even less competent if he lacks the technical knowledge relating to the line or staff activities where decisions must be rendered. The following corollary, then, stresses the vital importance for effective management of a proper blend of technical competency and reasoning ability. This is the critical need of modern management.

COROLLARY 2. Decision Making and the Factor of Time

All decisions are closely correlated with the factor of time. There are at least two aspects of this relationship worthy of analysis at this point. The first aspect concerns the appropriate moment for making decisions. The second relationship concerns the diminishing effectiveness of a decision with time progression. Both these aspects are subject to sound judgment and consequently cannot be controlled by strict adherence to any known formula.

The appropriate time for making a decision can be determined only by a careful analysis of all pertinent elements. Some of these elements are constant in character, that is, their effect perdures regardless of environmental or circumstantial changes. For example, the length of one complete night-day cycle is rigidly fixed by forces beyond the control of any human being. The great mass of elements which influence decision making, however, are variable. Thus, even though the night-day cycle is fixed in absolute duration, there is a variation in the length of a day due to seasonal factors. Then too, climatic conditions can slightly modify the effective length of daylight and darkness.

Since the number of elements, constant and variable, can range from a few to very many, technical competency is absolutely vital in their selection and evaluation. Common sense should indicate that in a hypothetical situation directly influenced by a total of 10 elements, only 2 or 3 might be of paramount importance. Delving too deeply into the remaining 7 or 8 would undoubtedly delay issuance of the decision, increase costs, and compound confusion. Factor selectivity, then, is mandatory. The exact number of elements which an administrator can consider in detail is subject to variance. However, as was demonstrated in the discussion on the Span of Control (corollary 2, Chapter 6), arithmetic increases in causal elements result in a geometric progression in the number of possible relationships. In some-

what a similar fashion, when more than 4 or 5 very important elements, and specifically variables, must be analyzed, the decision-making process becomes exceedingly complex. Consequently, in addition to factor selectivity, it is important to keep factors, and especially variables, at a minimum.

Reduction in the number of pertinent factors analyzed can have drastic consequences if essential elements are ignored. This frequently happens when the decision maker is immature, uninterested, uninspired, or incompetent. One of the soundest approaches to this problem is to convert variable elements into constants wherever practicable. This will reduce significantly the number of alternatives the decision maker must study. Another, and very feasible, technique is the application of division of labor. Breaking down a major decision into its component parts permits a regrouping of elements so that each subdecision rests upon fewer pertinent elements. This procedure is the basis for all forms of functionalization.

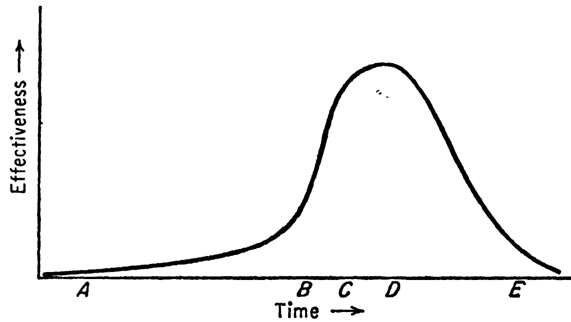
Factor selectivity, reduction of pertinent elements to a minimum, and conversion of variables into constants are all vital to timing and sound decision making. The precise moment when a specific decision is to be put into effect can seldom be established by rigorous rules. There is, however, a speed factor which serves to maximize the effectiveness of the decision. While a good administrator is never rash and impetuous in resolving an issue, much less is he a procrastinator. What is sometimes erroneously labeled deliberation is merely a manifestation of gross incompetency. While there are consequences to errors of commission, following from hasty decisions, there are, in a dynamic society, even more serious effects from errors of omission. One of the most obvious characteristics of a good administrator is the spontaneity and speed with which he will make a decision once he has analyzed all elements. If he is technically competent, well versed in principles of management and the characteristics of his own and related industries, there is seldom need for excessive delay in coming to a conclusion.

This speed factor is exceedingly important in highly competitive situations. Over a period of several decades United States Steel Corporation gradually relinquished a major share of its dominant position in the steel industry to its competitors. One of the basic reasons for this relative decline was the inability of this giant corporation's leaders to make sound decisions with the requisite speed and assurance. The mammoth was easily outmaneuvered, outrun, and outperformed by its more agile competitors. A similar example of the consequences of indecision was provided in the last decade by the relative decline of

Montgomery Ward and Company as compared with progress made by its major competitor, Sears, Roebuck and Company. Adherence to the slow-but-sure philosophy manifested itself in a slow-but-sure decline of the corporation. Fortunately, in both instances, the immense resources of the concerns enabled them to hobble along. Even more fortunately, both corporations have since radically modified their decision-making apparatus, with significant improvement in the timing and caliber of decisions.

Exhibit 7-2 shows, on the horizontal time scale, five points in time, *A, B, C, D,* and *E,* at which a specific decision might hypothetically be made. The obvious conclusion is that the maximum benefits would accrue if the decision were made at point *B* or between points *B* and *C.* Too early an application of the decision can result in higher administrative costs and ineffectiveness due to prematurity. While point *D* is

Exhibit 7-2. Hypothetical Need for a Specific Decision



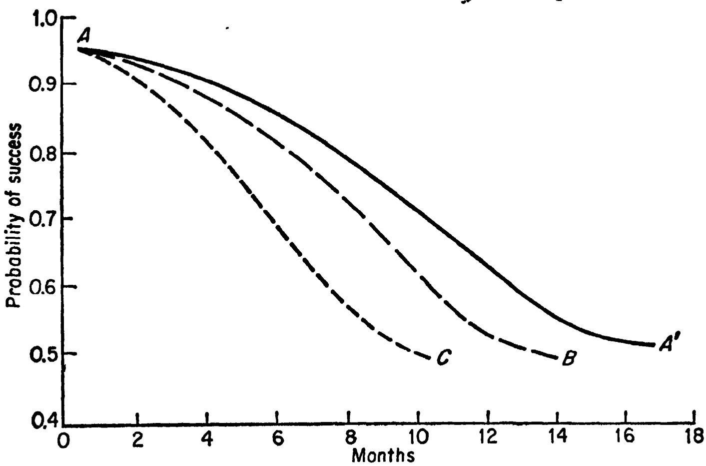
still high on the effectiveness scale, the rapid drop in the curve indicates a short remaining span of usefulness.

The second aspect, the diminishing effectiveness of a decision with time progression, is shown graphically in Exhibit 7-3. The probability that a specific decision will be consumated effectively is indicated on the vertical scale. The lower end of the scale ends at .5 probability since presumably a 50-50 possibility of success can be secured from reliance on chance alone. This does not obviate the danger of making decisions which can have serious negative consequences. The figure is restricted to the positive aspect on the assumption that a prudent and competent administrator should seldom consciously make decisions which have less than a 50-50 chance of success.

This diagram depicts a specific decision with an initial probability of success of .95, that is, with odds of 19 to 1 (95 chances out of 100 cases) that the decision, if put into effect immediately, will then and

there be successful 95 per cent of the time. However, with the progression of time, as indicated on the horizontal scale, the probability of success tends to decline. By the end of the year the chances for a favorable result, as shown on curve *AA'*, have declined to 63 out of 100. Curve *AA'* assumes that only one major variable factor influences the decision. Curves *AB* and *AC* show the hypothetical influence of one and two additional factors. This influence can best be shown by injecting an assumption that, in this specific case, a probability of success of at least .8 was considered critical. This minimal level, on the basis of one vital variable factor (curve *AA'*) was reached by the eighth month after the decision had been made. In the two-variable situation (curve *AB*), the lower level of expectation was reached in about 6½ months.

Exhibit 7-3. Time-Success Relationship



Introducing a third variable (curve *AC*) reduced the decision's effectiveness, timewise, to only 4 months.

In conclusion, the effectiveness and durability of a decision are closely correlated with:

1. Proper identification of pertinent factors
2. Judicious selection and analysis of the vital factors
3. Limitation of these factors to a workable minimum
4. Conversion of variable factors into constant factors
5. Speed and assurance in rendering decisions
6. Proper timing so that the maximum effect is realized
7. Prompt revision as the passage of time intensifies variability in the pertinent factors and introduces additional unknowns, thus devitalizing the decision

SIGNIFICANCE

An organization is vitalized or enervated by the decisions its leaders make. This correlation is both intimate and immediate. Despite the immense resources possessed by most large corporations, injudicious decisions can result in debilitation and ultimate liquidation for even the largest of enterprises. The decline and demise of American Woolen Company and United States Leather Company are illustrative. Both these concerns were at one time termed monopolistic trusts in their respective industries. The inability of their top-level decision makers to keep pace with a dynamically changing economy led to the eventual dissolution of these once great concerns.

The examples of the United States Steel Corporation and Montgomery Ward have been cited to stress the consequences of the "too little and too late" attitude in respect to decision making. United States Steel, while it is still referred to as Big Steel, suffered a relative decline during the past half century. It now controls less than one-third of the steel and iron market as contrasted with the two-thirds share it once held. Of all the reasons advanced as explanations for this decline, the most plausible seems to be U.S. Steel's former very cumbersome decision-making mechanism. Montgomery Ward's relative decline, as contrasted with the progress of its prime competitor, Sears, Roebuck, is likewise illustrative of the consequences attached to ineffective decision making. Within less than a decade, Sears, Roebuck increased its sales and assets ratios, as compared with Montgomery Ward, from about 2 to 1 to more than 3 to 1.

Agility in decision making is an essential for organization survival. Imagination in the concern's decision makers is equally requisite. Assurance, based upon technical competency and adequate facts, increases the probability that the decision will be successfully applied. While every rational being must frequently exercise his decision-making powers, it should be clear from the presentation in this chapter that much more than the native power or even the attribute of common sense is requisite to effective decision making in the sphere of industrial management. The innate power of reasoning is a prime essential. However, an intensive study and a diligent application are mandatory before one can become proficient in the art of decision making. Presumably, as improvements are made in scientific methodology and as reliable data become more available, a full-fledged science of decision making will be more widely recognized.

The subject matter in this chapter has dealt almost exclusively with those aspects which constitute the art of decision making. In the fol-

lowing chapter the focus will be upon statistical tools and techniques which might be used to implement sound judgment. In this context, the next chapter can be considered as an introduction to the gradually developing science of decision making.

ILLUSTRATION 1. Decision Making in Soviet Industry

. . . Consider a more prosaic item: Shoes. Alexander Chernischov, the affable director of Shoe Factory No. 4 in Kiev, the third largest Soviet city, says national shoe production now is running at an annual rate of about 350 million pairs. The 1960 goal is 455 million, or a little better than two pairs per Soviet citizen. By contrast, U.S. shoe factories last year turned out 510 million pairs—an average of about three pairs for each American.

Shoes not only come out of Soviet factories in smaller quantities but also in fewer styles. Mr. Chernischov's factory makes a full line of men's, women's and children's shoes, plain and fancy. With a total work force of 3,800, it is currently turning out about 50 different styles, but at peak demand periods of the year it may produce as many as 80.

In the U.S., a single plant may turn out even fewer styles. A typical U.S. factory concentrates on mass production of a few styles. But a U.S. shoe company, with a number of factories, may turn out 300 to 400 styles of men's shoes, 500 or more styles of women's shoes and some 200 styles of children's footwear.

How does Mr. Chernischov decide what shoe styles to produce, in what quantity and at what prices?

The quick answer is that he doesn't decide; the state tells him, and all other factory managers regardless of product, how much to make and at what price. But that only begs the question. How does the state know?

This is the basic economic problem confronting Soviet planners. It arises because the Soviet Union does not have an economy in which, as in the United States, production, styles and prices are largely determined by the indirect bargaining of consumer and producer. Through this process, the economists will tell you, the market economy performs its most important function—the direction of resources in such a way as to permit balanced growth.

Here in the Soviet Union, by contrast, total planning is substituted for the market, in theory anyway. So the question becomes, how do the planners know what to plan, and how do they keep the economy from getting completely out of whack? . . .

Within the ponderous superstructure of bureaucratic direction—there are no less than 48 Soviet ministries concerned with economics, many of them duplicated in the individual republics—a primitive kind of market economy does operate.

"For cost reasons," says Mr. Chernischov, "we'd naturally rather keep down the number of styles, but the stores insist on new ones." The stores, in turn, are motivated by the desire to sell more, and their ideas on what kinds of

styles people want come from suggestions, requests and complaints of the customers—in other words, from the market-place. In addition, the customer has his say by just not buying a particular style, thus forcing the factory to discontinue it.

The disagreement between store and factory over how many styles is resolved through meetings of representatives of each, plus officials of the government ministries concerned. . . .

"Soviet planning," says Gosplan Chairman Baibakov, "is from the bottom up as well as from the top down." In theory, at least, factory managers get some of their ideas about what, how much and how to produce from the workers, and these are incorporated into their own plans, which are sent to the appropriate republic ministry, modified and eventually find their way to Gosplan. Meantime, Gosplan has been devising its own master plan, with which the local efforts must be reconciled, often enough to the disadvantage of the latter.[2]

QUESTIONS

1. What similarities and what differences are there in industrial decision making in the United States and in Russia?
2. Referring to Chapter 4 on Concept of Standardization, does it appear that Russian shoe manufacturing has made more progress in the direction of standardization than has American industry?
3. Does Soviet decision making in industry manifest any characteristics of groupthink?
4. Comment on Gosplan Chairman Baibakov's statement that "Soviet planning is from the bottom up as well as from the top down."

ILLUSTRATION 2. Economic Prediction

The following is an excellent illustration of the dangers inherent in decision making when the number of factors, constant and variable, is extremely large and when the time span is extended. J. A. Livingston, financial adviser of the Philadelphia *Evening Bulletin,* began a systematic polling of 50 leading economists from labor, government, universities, banks, industrial corporations, and investment houses. His basic question concerned what the economists thought the Federal Reserve index of industrial production would be 6 months, 12 months, and 18 months after the date of survey. "Despite the diversity of background," comments *Fortune,* "there has been a considerable uniformity in the economists' answers. Most of them have been wrong most of the time." [3]

While some allowances might be made for unpredictable factors, and specifically national and international crises, it is hard to conceive

[2] Joseph E. Evans, *Through Soviet Windows,* Dow Jones and Company, Inc., New York, 1957, pp. 41–42.

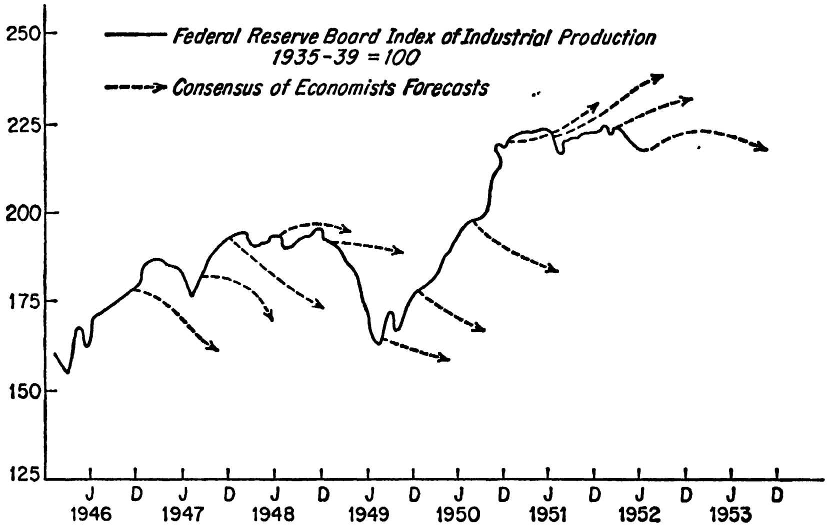
[3] *Fortune,* August, 1952, p. 28.

that a group of eminent technicians should be so consistently incorrect. Some of the answers are probably found in corollary 2.

QUESTIONS

1. On the basis of performance as shown in Exhibit 7-4, would a crystal ball or recourse to a modern Oracle of Delphi give equally reliable predictions?
2. What might be some of the major reasons for the wide margins of error?
3. How far could a businessman proceed in using this group of economists' predictions as a basis for making decisions regarding his enterprise?
4. What are the prospects that better predictions might be forthcoming in the future?

Exhibit 7-4



SOURCE: Business Roundup, *Fortune*, August, 1952, p. 28.

ILLUSTRATION 3. Deriving a Theory of Decision Making

While every rational being is an individual decision-making mechanism, very little is presently known about what sparks this mechanism into action and how it operates. Professor Herbert Simon and six colleagues at Carnegie Institute's Graduate School of Industrial Administration have been working, since 1953, on a Ford Foundation–financed research project seeking such evidence. The half-million-dollar venture has thus far yielded relatively few conclusions. However, among the tentative generalizations are the following:

1. Formal investigations with the express purpose of formulating a decision are generally initiated when the decision in question has already been tacitly accepted. What is generally considered to be the

decision-making process is consequently merely a corroboratory, ex post facto analysis.

2. The great mass of decisions are made on a "follow-the-leader" basis. A few bellwether companies set the precedent, and the mass of business enterprises placidly follow their leadership.

3. This means that executives are even guided into the specific areas in which they will make their already "patterned" decisions.

4. It can be inferred from the foregoing three conclusions that the great majority of executives seldom make entirely "new" decisions and are very cautious even in emulating the examples of their peers.

These conclusions bring to mind Polonius's advice to Laertes: "Be not the first by whom the new is tried, nor yet the last to lay the old aside," and the more forceful words of Alexander Pope: "Fools step in where angels fear to tread."

This stress on caution is important especially when the course of action is not clearly marked. It is highly probable, however, that the so-called caution of many executives is a composite of fear, lack of application, and incompetency. Presumably the results of Simon's long-range experiment should assist administrators in a better understanding of what factors and forces lead to decision making, or to indecision.

In particular, the group hopes to discover how individuals can make decisions when only inadequate data are available. They point out that electronic computers can solve extremely complex mathematical problems but only when the machine is properly set to work on such problems and when all necessary data are provided. Human beings seem to skip through entire sequences of reasoning and, while matching the speed of computers, solve extremely complex problems involving many constants, variables, and even many unknowns. Simon believes that such decision making, with incomplete data, resembles the high-school geometry student's approach to a new theorem which he must solve by himself. Invariably he will draw on his experience, relating the new theorem to those with which he is already well acquainted. The solution is then arrived at by fitting the components of the problem to the accepted logical structures and drawing inferences. These inferences, specifically where the information is scanty, must frequently entail hunches, intuition, and even the blind action of trial and error.

Out of their experimental work, the Carnegie Institute group hopes to determine not only how the decision-making process functions but what personality characteristics are most important in producing the most effective decision maker.

QUESTIONS

1. What is the probability, in your opinion, that a theory of decision making comparable with the theories of relativity, of value, or of probability will be developed within the near future?
2. What relationship would corollary 2, Decision Making and the Factor of Time, have to a sound theory of decision making?
3. Do the tentative conclusions of this study support groupthink?
4. Why might lengthy and costly investigation, purportedly to formulate a decision, be ventured when acceptance of that decision has already tacitly been made?

ILLUSTRATION 4. Three Famous Formulas for Thinking Up Ideas

Exhibit 7-5

John Dewey's: Normal (normal thought process)	General Electric's: Structure (patterned approach)	Alex F. Osborn's: Free-wheeling (applied-imagination sequence)
1. Determine real problem	1. Recognize 2. Define	1. Orient—point up problem
2. Gather all facts	3. Search	2. Prepare—gather pertinent data
3. Analyze the problem—obstacles to be overcome	4. Evaluate	3. Analyze—break down relevant material
4. List possible solutions for overcoming obstacles	5. Select 6. Make preliminary design 7. Test and evaluate	4. Hypothesize—pile up alternatives by way of ideas (brainstorm) 5. Incubate—let up to invite illumination 6. Synthesize—put the pieces together
5. Develop plan of action	8. Follow through	7. Verify—judge resultant ideas

SOURCE: "How to Make Good Ideas Come Easy," *Factory Management and Maintenance,* March, 1956, p. 86.

QUESTIONS

1. In what respects does Chapter 7 coincide with these three formulas?
2. Are there any major differences in sequence or technique?
3. Which formula seems to be the most practical?

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CHAPTER 8

Decision Making—Mathematical Analysis

DEFINITION AND DESCRIPTION

It can readily be inferred from the preceding chapter that every manager is a decision maker. In this capacity the manager must be competent to appraise a given situation, endeavor to control the pertinent factors, predict the probable outcomes under hypothetical conditions, and then select the most desirable courses of action. While no substitutes have been found for sound judgment and a good sense of values in the fulfillment of these management functions, there is a great variety of mathematical aids which the technically competent manager can use to facilitate fulfillment of his functions. This chapter will present a summary discussion of a few of the steadily increasing number of mathematical tools useful in decision making.

Mathematical devices are feasible only in such instances where pertinent factors and conclusions can be expressed in numerical terms. The more precise the measurement, the greater is the likelihood that such information can be satisfactorily used in formulating a decision. Even in those cases where the basic data are presumably qualitative in character, quantification can usually be applied by means of ingenious approximations and correlations. Value judgments, while lacking the exactness and certainty of precise physical measurement, can nevertheless be used effectively in mathematical decision making.

In the previous chapter it was pointed out that the process of decision making is concerned with appraising all known alternatives and then selecting a single course of action that is to be followed. Prior to this selection, the outcomes for each alternative must be predicted. These several probable outcomes must then be evaluated according to some acceptable scale of desirability. The actual selection should be made in terms of maximizing both the probability of attaining the goal and the resultant desirability. In other words, a highly desirable course of action with very little likelihood of attainment should generally be superseded by a less desirable course of action which has considerably more chances of realization. This fundamental proposition is depicted in Exhibits 8-1 and 8-2.

Exhibit 8-1

Course of action	Probability of attainment	Degree of desirability
A	10	1
B	6	8
C	2	10
D	1	5

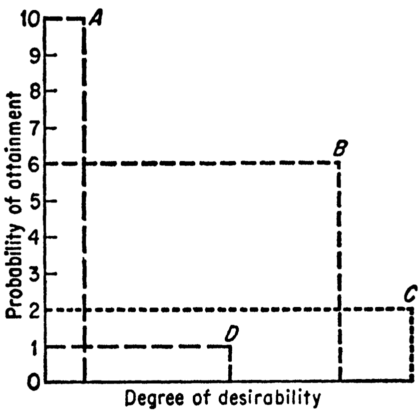
In the hypothetical situation depicted, one of four alternative courses of action, *A, B, C,* and *D,* can be elected. These four choices vary as to probability of attainment and degree of desirability. Alternative *A* is presumably 10 times as likely to be achieved as is alternative *D.* However, judged by the specific value system, the product of alternative *A* brings relatively the least satisfaction since alternative *D* is 5 times more desirable while alternative *C* yields results 10 times more desirable. In this specific case, assuming that probabilities and desirability can be equated in these simple terms, alternative *B* seems to be the best course of action to follow. Exhibit 8-2 shows the relative superiority, in graphic form, of alternative *B.* This superiority is indicated by the greater area encompassed within the *B* rectangle. While this illustration might appear to oversimplify the decision-making process, it does point out the vital components of all types of selection. These components include:

1. Recognition of alternatives
2. Quantification of terms and results
3. Application of a prediction system
4. Equating by a value system

5. Selection of the alternative which maximizes the probability of attainment together with the degree of desirability

The crux of mathematical decision making resides in the ability to quantify all pertinent factors. It would, obviously, be ridiculous to expect every individual to express numerically his reasons for selecting specific courses of action. In the great majority of cases a simple "I believe . . . ," "I feel . . . ," "I think . . . ," etc., is adequate to indicate that alternatives have been compared and a choice has been made. Then too, it is not always necessary to consider every possible alternative. Some of the possible courses of action are either so unlikely to be attained or the results provide so little satisfaction that these choices can be immediately eliminated. Thus the range of alternatives

Exhibit 8-2. Preference Quantification of Four Alternative Courses of Action



tends to be reduced in most situations to a workable minimum. It is within this practical and limited range of alternatives that mathematical analysis can be effectively employed to aid the decision maker.

The first step in comprehending mathematical management is an understanding of the concept of probability. In the beginning of Chapter 2, reference was made to probability as being concerned with determining the likelihood that, under certain circumstances, a given chance event will occur. Some of the best illustrations of how knowledge of the laws of probability can be applied have come from studies of games of chance. For example, under normal conditions, in rolling a six-sided die, there should be equal probabilities that any one of the six sides should turn face up. Using a pair of dice, however, will give the probabilities computed in Exhibit 8-3.

Knowledge of the probability of occurrence can be extremely useful in predicting outcome. For example, in Exhibit 8-3, an individual selecting all five combinations 5, 6, 7, 8, and 9 would normally be successful twice as often as an individual who had selected the six numbers 2, 3, 4, 10, 11, and 12. This is true despite the fact that the first individual had only five numbers versus the second person's six numbers. Even more illustrative is the fact that the chances of a 7-point combination are six times as likely as the chances of either point combination 2 or 12. Obviously, adding a third, fourth, or fifth die will cause significant changes in the likelihood that any single number will be rolled.

This simple illustration presupposes certain conditions. The dice must be nearly perfectly hexagonal with no biasing by weights, cuts, etc. More important, enough tosses of the dice must be made so that

Exhibit 8-3

	Point combination										
	2	3	4	5	6	7	8	9	10	11	12
Probability of occurrence per 1,000	28	56	83	111	139	166	139	111	83	56	28

there is a sufficiently large number of cases upon which to base conclusions.

These premises are mentioned merely to emphasize that valid and reliable probability analysis always assumes certain standard conditions. Every time a premise is modified, willfully or by force of circumstance, adjustments must be made in the calculated probabilities.

The preceding illustration of probability of occurrence in the dice-tossing experiment is necessarily elementary in character. Mathematical analysis of industrial problems generally requires more complex techniques. One of the most commonly used concepts in this category is the normal probability curve, also known as the normal curve, the normal curve of error, and the Gaussian curve. This curve is the product of the expansion of the binomial $(a + b)^n$.

The basic theory dates back to 1733 when Abraham Demoivre wrote a mathematical treatise explaining how the binomial $(a + b)^n$ could be expanded into a series which could be expressed graphically by a symmetrical curve. Demoivre suggested no practical application for his theory except in a few problems incident to games of chance. Gauss, whose name is closely linked with this curve, demonstrated the theory's utility in scientific analysis such as the study of accidental

errors of measurement connected with the calculation of orbits of heavenly bodies.

Among the several logical assumptions in the construction of a normal probability curve are the following:

1. Randomness. There is an equal chance that every pertinent item within the universe being studied can be selected for the sample to be analyzed.

2. Adequate Sample Size. Too small a group will tend to yield unreliable and invalid results. Too large a sample can prove to be unwieldy, and the analysis extremely costly.

3. A Symmetrical Distribution of Probabilities. This means that small errors or deviations are more likely to occur than large errors or deviations, that very large errors or deviations are unlikely to occur, and that positive and negative errors of the same numerical value are equally likely to occur.

4. The Centripetal Pull of Central Tendency. This is a fundamental proposition in statistics stating that if a sufficiently large number of items containing a variable chance factor is studied, this characteristic will tend to be distributed equally about a central point. In corollary 2, Chapter 4, this phenomenon is designated (Exhibit 4-5) by the perpendicular line *MM′* bisecting the distribution so that half the items have values less than that of the measure of central tendency while the other half has greater values. Despite the relatively wide range, as expressed by the line *AA′*, most of the items tend to cluster around the line *MM′*. The most commonly used measures of central tendency are the (1) mean, a simple arithmetic average, (2) median, the mid-point in an array of values, and (3) mode, a point or class of maximum cluster.

5. The Centrifugal Force of Dispersion. The best-known concept relative to dispersion is standard deviation, represented by the symbol sigma (σ). One standard deviation on either side of the measure of central tendency ($\bar{X} \pm \sigma$) will include approximately 68 per cent of the items being studied. Two standard deviations on either side of the measure of central tendency ($\bar{X} \pm 2\sigma$) will include about 95 per cent of the group; while three standard deviations will account for 99.73 per cent, or all but 27 items of a group of 10,000.

The mathematical manager must be acquainted with at least the logic underlying probability distribution as derived from the expansion of the binomial. The familiar sequence:

$$a^n + na^{n-1}b + \frac{n(n-1)}{(2)(1)}a^{n-2}b^2 + \frac{n(n-1)(n-2)}{(3)(2)(1)}a^{n-3}b^3 + \cdots$$

provides numerical values. In a situation where a particular event will happen (p') or will not happen (q'), these numerical values can easily be determined. Even in more complex problems, as in the sphere of statistical quality control, prediction is facilitated. For example, in a given industrial situation past records indicate that a specific process yields, on the average, products which meet the prescribed specifications 94 per cent of the time. The average likelihood of defectives might be expressed as $p' = 0.06$, while the likelihood of defective nonoccurrence is $q' = 0.94$. If samples of 5 items each are selected at random from the process, the chances that none of the items will have the defective characteristic is expressed in the term q'^n, or $(0.94)^5$, which equals 0.734, or 734 chances out of 1,000. The probability that one of the 5 items will possess this trait is expressed by $nq'^{n-1}p'$, which is readily converted into $5(0.94)^4$ (0.06), or 0.234. This means that the combined probability, in this case, of getting none (P_0) or one (P_1) defective in the 5-item sample is $0.734 + 0.234 = 0.968$. Thus the likelihood of obtaining P_2, P_3, P_4, and P_5, or 2, 3, 4, and 5 defective items in a single sample, is relatively remote. Actually, the likelihood of P_3 is less than 2 out of 1,000 and that of P_4 and P_5 is almost insignificant. By varying n, p', and q' values, a considerable range of probabilities of occurrence or nonoccurrence can be computed.

Poisson's exponential binomial limit is an accepted short-cut device for deriving normal probability curves. The Poisson distribution, although it yields results less exact than those obtained from the conventional binomial expansion, is timesaving, sufficiently accurate, and easier to comprehend. The Poisson is obtained from an expansion of $C^{-np'}$, where C is the base of the natural, or Naperian, logarithms with a value of 2.71828+. In the Poisson distribution, $C^{-np'}$ represents the probability of no occurrences, $np'C^{-np'}$ is the probability of one occurrence, etc. The Poisson is mentioned at this point to illustrate how, with continued experimentation, relatively complex and theoretical techniques can be modified into less complex and more practical devices.

Mathematical management relies on a great variety of similar devices. For example, a commonly used modification of the equation of the normal curve is expressed as

$$Y_c = \frac{Ni}{\sigma\sqrt{2\pi}} e \frac{-x^2}{2\sigma^2}$$

where Y_c = computed height of ordinate at distance x from arithmetic mean

N = number of items

i = class interval
σ = standard deviation
π = a constant whose value is 3.14159
$\sqrt{2\pi}$ = 2.5066
e = base of Naperian system of logarithms, with a value of 2.71828
x = selected deviation from arithmetic mean

The technique of fitting the normal curve to data pertinent to specific situations is a function of statistics and as such is somewhat beyond the scope of this text. However, an acquaintance with basic concepts, terms, and techniques can be most helpful in scientific decision making. Among some of the terms which the mathematical manager should know in connection with the use of statistics relative to the management function are the following:

1. *Chance Factor.* A pertinent element which is inherent in a stable causal system. Modification of chance factors can be effected only by changes within the system's framework.

2. *Assignable Factor.* A pertinent element which is largely external to the stable pattern of the causal system, yet exerts influence upon this system by inducing variations in effects. Isolation of assignable factors is basic to any attempt at control over a causal system.

3. *Parameter.* A factor or variable affecting a process or operation.

4. *Correlation.* A mathematical method for relating one factor to another and measuring the extent of relationship. A series of correlations is termed a regression. A line of regression is an algebraic statement showing the nature of the relationship among the variables.

5. *Statistical Inference.* This is the use of statistical tools in decision making.

6. *Forward Probabilities.* These are associated with event chains which move progressively forward step by step.

7. *Inverse Probabilities.* These probabilities are concerned with a backward movement along the chain of events.

8. *Theorem of Total Probabilities.* This is also known as the addition rule and refers to the probability of occurrence of either one or another of any number of mutually exclusive events, which is the sum of the probabilities of the separate events.

9. *Theorem of Compound Probabilities.* This is the multiplication rule. It states that if an occurrence is made up of several independent subevents, the occurrence of the compound event is the product of the probabilities that each subevent will happen.

10. *Theorem of Conditional Probabilities.* This theorem states that

the probability that both of the two dependent events will occur is the probability of the first event multiplied by the probability that if the first event has occurred, the second will also happen.

11. Mathematical Models. Quantitative analogies of operational problems are referred to as mathematical models.

12. Deterministic Models. This version of mathematical models represents situations where all important variables are management-controlled.

13. Stochastic Models. This type, also known as probability models, contains some important variables beyond the control of management.

14. Game Models. These models are useful in depicting the behavior of two or more competitors under given circumstances.

Although this approach to statistics is patently elementary, it should be adequate to focus attention upon the tremendous potential of mathematical analysis in decision making. Some managers, and an even greater portion of would-be managers, assiduously avoid having recourse to any form of mathematics beyond simple computation in the making of decisions, on the plea that decisions are subjective and beyond measurement. Such shunning of mathematical tools is generally due to inadvertence, improper training, or outright incompetence. While the quasi manager might avoid mathematical tools, he invariably stresses the importance of "common sense" in decision making. What such an individual fails to realize is that proper use of these tools simply provides an extension to and a refinement of common sense. The manager who can convert his common-sense solution of a problem into measurable terms is much better able to cope with the situation by more readily discerning the best alternatives and assaying the odds as to probable outcomes. In contrast, the nonmathematical manager has no guide except intuition upon which to base selection. In effect he must rely upon hit-and-miss techniques. Dependence upon such crude techniques invariably handicaps such a decision maker, impairing his effectiveness. He will tend to go to either extreme, becoming either overcautious or impetuous. Overcaution is the product of fear and uncertainty, following from ignorance of the pertinent facts and an inability to appraise probable outcomes and degrees of desirability. Impetuosity stems from a similar state of ignorance. While the overcautious tend to exaggerate the negative aspects, the impetuous are blind to consequences. In summary, tomorrow's successful manager must put greater reliance in the available mathematical aids for more effective decision making. The utility of these tools has already been demonstrated in areas such as quality control, work measurement,

machine loading, equipment replacement, wages studies, and market analysis.

DEVELOPMENT

Simple arithmetic has been employed in computational work, record keeping, and for control purposes in business since the inception of civilization. The Code of Hammurabi, previously mentioned, is a classic example testifying to the ancients' knowledge and acceptance of fundamental arithmetic in connection with affairs of state and business. The Bible has numerous references to computations and record keeping. Similar examples can be found in the literature and recorded history of all ancient civilizations. The contributions of the ancient Greeks, including such pioneers in the sphere of mathematics as Pythagoras (late sixth century B.C.) and Euclid (late fourth century B.C.), helped create a science of mathematics with specialized spheres such as geometry and calculus.

While these basic components of the mathematical discipline might have had some incidental value to decision making in business, there was, until recently, very little direct application. Mathematical analysis in decision making had its inception with the introduction of the theory of probability in the mid-seventeenth century. The renowned scientist Blaise Pascal was asked by some gambler acquaintances to work out a set of mathematical probabilities by which odds could be determined for bet making in dice games. In 1662 an Englishman, Captain Graunt, applied Pascal's principles to a study of the London death register. His tables of life expectancies were the beginning of an actuarial science upon which all modern insurance rate setting is based. Within the next fifty years, major theoretical contributions were made by the renowned mathematicians Bernoulli and Halley. The latter, because of his work in astronomy, had the distinction of having a comet named after him.

Despite considerable progress during the eighteenth and nineteenth centuries, in the development of probability theory, it was not until this century that the theory became more widely accepted. The works of K. Pearson, R. A. Fisher, L. Tippett, and W. A. Shewhart, in particular, did much to stimulate the application of the theory to business problems.

The interval of nearly three centuries between the discovery of probability theory and its practical application in business focuses attention upon its basic limitations. Decision making, through the use of probabilities, rests upon the onerous and costly process of gathering

large masses of pertinent data. Such collection requires not only patience and money but also sound judgment to determine what data are relevant and what decisions are feasible. Another serious limitation is the difficulty of translating certain types of data into numerical values. Nevertheless, this quantification is imperative. If the likelihood of occurrence of various events cannot be expressed arithmetically, then comparisons tend to become subjective and the value of the scientific method is seriously abridged. The application of probability theory to industrial problem solution was particularly handicapped because of the high cost incident to gathering, classifying, and correlating the pertinent data and finally making adequate inferences.

In the evolution of computing devices, one of the earliest and highly proficient contrivances was the Chinese abacus. This ingenious gadget, consisting simply of a series of strings of beads, can be used in solving complex arithmetic problems. The abacus, however, has several basic limitations making it inadequate for modern business needs.

The first known attempt at constructing a truly mechanical calculating contrivance was made in 1642 by Blaise Pascal. Nearly two hundred years later Charles Babbage proposed a punch-card-operated calculating machine similar to models currently in use. Engineering skill, however, was inadequate at that time to put his novel idea into practice. It was less than seventy years ago that the first successful office mechanism was developed for multiplying and dividing mechanically. This device and most subsequent improvements have operated somewhat in the fashion of the Chinese abacus. There are 10 mechanical appendages, that is, teeth with gears. A predetermined number of revolutions of each gear wheel moves an adjacent gear a single revolution. The cumulative revolutions are then recorded on a panel.

While manually operated calculators have been in use for nearly seven decades, automatic computers date back only to Mark I, the remarkable robot calculator devised by the collaboration of the International Business Machines Company and Harvard University soon after World War II. Mark I is a relay-type computer with the toothed gears basic to manual calculators being replaced by electronic relays. The first all-electronic computer, called ENIAC (Electronic Numerical Integrator and Calculator), was built at the University of Pennsylvania in 1945 for the Army's Aberdeen Proving Grounds.

In the electronic computer there are no moving parts. Vacuum tubes, germanium diodes, capacitors, electrostatic devices, and similar components perform the requisite functions. Some of the actions are extremely rapid with "on" and "off" switching consuming as little

as one-millionth of a second. In contrast with this fantastic speed of electronic computers, electromechanical equipment operates at speeds of 20 to 200 cycles per second.

While high-speed calculators for data processing and problem solving are a relative innovation in the industrial sphere, their potential seems to be unlimited. This sketchy description of their development should call attention to the relative recentness of electronic contrivances in the field of data processing. In reference to the level of technology, it might be asserted that high-speed computers are still in the period of inception, subject to intensive experimentation and rapid technological change. A product passing through this phase is not too readily accepted by the consumer, primarily because of high initial cost, nonrecognition of its potential, and the real danger of rapid obsolescence. As high-speed computers advance beyond the technological stage of inception and into the period of rapid acceptance, these mechanisms should prove to be one of the most valuable components of scientific management.

COROLLARY 1. High-speed Computers

Basically there are two types of high-speed computers: digital and analog. The former operates in a fashion comparable with the Chinese abacus and the desk calculator. Counting is done in strict accordance with rules of logic and the discrete principle. Items are included or rejected on the basis of whether or not they possess the characteristic in question. Thus all calculations on the digital computer are expressed numerically. Carrying the quotients to an additional significant figure would, theoretically, add to the accuracy of such calculations. The analog computer, on the other hand, represents the several variables important to the solution of the problem by some controllable physical quantity such as voltage. This yields a product subject to instantaneous modification when the pertinent variables are changed. Because of this intimate interaction, answers from an analog computer appear in the form of a graph.

Despite the immediate and enthusiastic response given to electronic computers by the public, whose imagination was captivated by the unlimited potential of these mechanisms, their industrial application has been relatively slow. The first industrial installation of a big computer was made in 1954. Cost is paramount among the major limiting factors. Programming for a complex operation requires time, money, and even a regearing of company procedures and policies. Preparation costs, exclusive of charges for equipment, for a typical problem can range from $1,000 to $100,000. One reason for this excessive cost is the

need for highly paid, technically qualified programmers, who must spend many hours in preliminary analysis. The equipment cost is also a major impediment. *Fortune* estimated that a desk calculator could do 1 million mathematical operations at a labor cost of about $30,000. A general-purpose digital computer can do the same work at a cost of only $30. Equipment costs, however, were not considered in this comparison. Digital-computer prices range from $32,000 to nearly $5 million. The conclusion is obvious. These electronic mechanisms are economically feasible only where the volume of work is great enough to maximize the machine use to the point where its high overhead cost can be offset by more than proportionate labor savings. Considering the extreme speed of these devices, it should be apparent that only large organizations with high-volume operations would be in need of such high-speed, high-cost equipment.

Another serious obstacle to the rapid adoption of high-speed computers in industrial decision making is the apparent impossibility of adequately converting many business intangible items into numerical quantities. While quantified approximations can be ventured in respect to many subjective factors, there is always the danger that such quantification deviates considerably from the true value. Human emotions, personality traits, and similar subjective factors practically defy accurate measurement. Many of these intangibles are acquired by the inanimate corporation through the process of personification, described in Chapter 6. For example, even though the objective of all industrial enterprise is assumed to be the maximization of profits, it must be remembered that many other nonmonetary and nonquantifiable motives, such as pride, creativeness, and civic-mindedness, impel organizations and individuals into economic action.

As a final caution to the overzealous who advocate high-speed computers as the perfect replacement for managerial know-how and judgment in decision making, it should be emphasized that a machine's ability to gather and process information is rigidly limited by the machine designer's intentions and the operative's capabilities. If even one important parameter is overlooked, the conclusions of the costly process are neither valid, reliable, nor usable. Improper premises, despite mathematical wizardry, can yield only improper conclusions. No mechanism, including high-speed computers, can think. These mechanisms are only an aid to and not a substitute for reasoning. Furthermore, unless the cost warrants and there is a real need for the computations, recourse to high-speed computers can become an expensive hobby.

This stress on caution in the use of high-speed computers is not to

be construed as a condemnation. The digital computer has proved its worth in a great variety of uses, such as the processing of tremendous quantities of data in billing, payroll accounting, banking operations, actuarial studies, inventory control, and similar industrial activities. The analog computer has been proved to be a most valuable adjunct to mathematical analysis where variable factors affect a situation. Through the use of both basic types of high-speed computers, the need for large numbers of clerks to perform routine, uninteresting functions has been drastically reduced. Conversely, the need for higher human faculties, such as judging, valuing, recognizing relationships, and using imagination, has been greatly increased.

COROLLARY 2. Operations Research

One of the most recent additions to the management vocabulary is the term *operations research.* The term refers to the application of scientific techniques to the solution of complex business problems by the quantitative comparison of alternatives. In substance, operations research consists in the breaking down of a business problem into its pertinent factors. Experts then analyze the several phases and quantify and weigh each variable. The probabilities and costs of the many alternative courses of action are then expressed in numerical terms. The essential features of operations research include:

1. Breaking a problem down into its pertinent factors
2. Quantifying these factors
3. Applying statistical or mathematical techniques to determine the optimum combination of these factors
4. Using teams of experts to analyze each aspect of the problem
5. Making recommendations to managers as to the best course of action

These components of operations research are practically identical with the basic characteristics of scientific management. Actually, the former is simply a refinement of Frederick Taylor's recommendations. At best, operations research is a more advanced application of the scientific method to management problems in business. This progress has been made possible by the availability of high-speed computing machines, such as IBM's 701 Computer, the CRC, and the Univac. With these high-speed computers problems involving more variables and more complex combinations of these variables can be more readily solved.

Probably the first attempt at illustrating economic interrelationships in a quantitative fashion was made by François Quesnay. His well-known *Tableau Economique,* presented in 1759, depicted in hypo-

thetical aggregate figures the flow of money receipts and expenditures, together with the flow of goods and services between related sectors of the French economy. The effect upon the system of modifications in any of the variable components could be measured quantitatively. A century later the Walrasian system of general equilibrium developed the quantitative representation of economic systems into a highly scientific technique. Walras demonstrated how, in a static equilibrium, prices and quantities of services and produced goods could be calculated, assuming competition, specific utility functions, coefficients of production, and demand-and-supply functions. Such quantification of purportedly subjective factors was instrumental in the development of techniques for representing economic systems as linear models. Econometrics, the mathematical analysis of economic problems, is the culmination of research in this direction.

Although econometrics has matured into a full-fledged component of economics, its utility in industry, as of the present, has been minimal. Stress on macroanalysis, while intriguing from a theoretical point, contributes very little to immediate solution of industrial problems. This limitation of econometric macroanalysis is, to a certain extent, the prime handicap to the more effective utilization of operations research in industry. While operations-research proponents scoff at Frederick Taylor's experimental contributions as being elementary in contrast to the manipulation of complex mathematical models by operations researchers, it must be admitted that the basis for scientific management and the use of mathematics for industrial problem solution was established by Taylor and his contemporaries more than half a century prior to the inception of operations research.

Taylor anticipated operations research in the following ways:

1. He built mathematical models for specific industrial situations. His study of the science of metal cutting, in which he reduced the problem to an equation of 12 independent variables, is a classic illustration.

2. He used experts from related sciences to help resolve industrial problems. In Taylor's "operations research team" were the competent mathematicians Henry L. Gantt and Carl G. Barth, who developed the complex formulas for solution of metal-cutting problems involving any of the 12 independent variables.

3. He proposed standards, precepts, and laws for universal application to replace the rule-of-thumb norms in industry.

4. He based all industrial decisions on facts rather than upon fiction, emotion, or chance.

There are some obvious differences between Taylor's scientific man-

agement and the current operations-research fad. Taylor had no high-speed computers to simplify his computation labors. Thus Taylor's metal-cutting study, originally estimated to take six months, continued for twenty-six years. In the course of the study, as previously mentioned, nearly 50,000 individual experiments were made in which over 800,000 pounds of steel and iron were cut up into chips. The total cost of the experiment, in present-day dollars, amounted to about one million dollars. Taylor states that "after working 26 years, it has been found that the answer in every case involves the solution of an intricate mathematical problem in which the effect of twelve independent variables must be determined." [1] Among these variables were (1) the hardness of the metal, (2) the composition of the cutting tool, (3) the thickness of the shaving, (4) the shape of the tool's cutting edge, (5) the depth of cut, (6) the duration of the cut, etc. Out of such experimentation, Taylor's "team" developed a variety of scientific techniques.

Barth's contribution, the slide rule, proved particularly useful. Ordinary machinists could now solve in minutes complex problems which prior to the slide rule could only be solved by highly trained mathematicians, sometimes working for many days making the necessary calculations. Gantt developed an ingenious technique for graphic presentation in respect to production control. Gantt charts are currently used in every type of activity where sequence and timing are important. Gantt, Taylor, and several of their associates developed a number of mathematical schemes for wage-incentive systems.

These examples are cited to emphasize that the principles, techniques, and objectives of operations research are simply a reiteration of Taylor's fundamental thesis. During the past half century, management tools, such as statistical quality control, work measurement, economic-lot-size formulas, equipment-replacement formulas, and similar management aids, have anticipated operations research. What operations research does contribute, however, is a significant surge forward in what might figuratively be termed the "technological" development of the scientific-management concept. Operations research stresses the systematic construction of action models based on fundamental theory and a heavy reliance upon the more complicated mathematical concepts and techniques of science. This borrowing is not the first time that a given field of learning has made progress by incorporating the techniques and contributions of other fields. The stress upon experimentation, equations, parameters, etc., stimulates the use of the

[1] Frederick W. Taylor, *The Principles of Scientific Management*, Harper & Brothers, New York, 1911, p. 107.

scientific method. The building of mathematical models (certainty) and probability models (uncertainty) provides a quantitative conceptualization of a process, system, or set of operations under study. Prediction of results and comparison of values, effectiveness, and costs of any set of proposed alternative courses of action of any man-machine system are facilitated. Although mathematical methodology is the core of all operations-research techniques, it should be evident that sound logic is fundamental in every instance. In fact, British operations researchers have criticized their American counterparts for overemphasizing the complex mathematics. It is the contention of the British school that operations research can be nonmathematical. The essential feature is the application of scientific techniques to the solution of complex business problems by the quantitative comparison of alternatives.

COROLLARY 3. Queuing Theory

In any industrial situation employing serialization and synchronization there is always the danger of bottlenecks resulting from a breakdown in one of the process components. Waiting lines also result from improper timing between the arrival at a specific work station of a sequence of goods in process and the subsequent disposal of these units. The consequences of waiting lines and bottlenecks have long been recognized in industry. Remedial measures have led to numerous techniques for attaining balanced operations cycles. Methods analysis, work simplification, machine-load studies, economic-lot analysis, Gantt charting, process and flow diagraming are some of the better-known devices whose objective is the securing of optimum balance and timing of operations cycles. The entire function of production control, with routing, dispatching, scheduling, and expediting as its major components, is concerned with optimizing the movements of materials through the work stations. An excellent example of highly developed production control techniques as the epitome of serialized and synchronized operations is provided by the modern assembly line. Integration of and coordination among the various work stations are carried out to such a degree that any imbalance in the work cycle invariably results in bottleneck situations.

World War II problems of transportation led to the development of complex mathematical techniques for selecting the most efficient movements of men, materials, and equipment. The British, in particular, contributed much to research in this field by stressing the application of probability theory to transport situations. The concept of

holding or waiting time, long recognized in the switching phase of the telephone communications industry, provided a sound basis out of which a more elaborate queuing theory was generated.

Queuing theory is concerned with the construction of mathematical relationships among all the factors which affect the rate of flow and the rate of processing. The more important of these factors include:

1. The source of items
2. The transportation medium
3. The rate of input
4. The distance traveled
5. The nature of temporary storage at the destination
6. The processing rate

These parameters must first be quantified and must then be translated into mathematical symbols or letters. This facilitates mathematical analysis by means of equations which reduce complex descriptions and relationships to relatively compact forms. For example, a queuing equation, $P_n = (A/S)^n[1 - (A/S)]$, simply designates the probability that at a given time the waiting line will contain n items. In this instance n is an important variable, as are A, the average rate of input, and S, the average rate of servicing. It can readily be observed from this formula that changing the values of n, A, or S will yield varying probabilities as to the length of the waiting line. Such information can be of value to the decision maker who must determine, for example, whether it is economic to tie up working capital in long waiting lines of goods in process or whether it would be beneficial to add processing equipment. The decision maker must consider aspects such as:

1. The value of the items in the waiting line
2. The need for a "float" of material as a reservoir for continuous equipment utilization
3. The danger of deterioration of the items in the waiting line
4. The costs of acquiring overcapacity

While the queuing theory has shown the feasibility of applying complex mathematical tools to certain industrial situations, its widespread industrial application in the relatively near future is highly unlikely. This reservation is common to all the so-called operations-research techniques. Nevertheless, there is a very important immediate value provided by the queuing theory. It has focused attention upon the exceedingly high costs of transportation and storage incident to imbalance in operating cycles. This attention should result in a keener cost consciousness and a determination to improve productivity in this sphere by better production control methods.

COROLLARY 4. Information Theory

The technical aspects of this theory were first presented in two papers entitled "A Mathematical Theory of Communications," published by Claude Shannon of the Bell Telephone Laboratories. While many of the technical features of this theory are only indirectly pertinent to organizational communications and decision making, the basic theory does have application to the transmission of information to and within an organization structure. For example, it can be assumed that every communications medium has some optimum rate for carrying error-free messages. A less-than-optimum rate means that capacity is being wasted. A greater-than-optimum rate generally results in excessive straining of facilities with consequent increased incidence of low-quality output.

Information theory provides a mathematical means for computing the closest approximation to the error-free optimum. Mathematical models can be erected to show the requirements, benefits, and limitations of various alternatives. Thus the important components, such as the information source, its output rate, the channel capacity, the potential of the receiver, and the message fidelity, can be isolated, analyzed, and evaluated.

There is at least one very significant difference between the application of information theory to the technical field of communications and to the industrial application of decision making. In the broad field of communications, the combinations of signals, symbols, or alphabetic letters are almost limitless in their variety. Even though analysis indicates that some letters are more frequently used than others (for example, the letters *z*, *g*, *a*, and *e* are generally found in the proportions of 1, 14, 87, and 147, respectively, in the English language), it is practically impossible to predict the next letter of a message unless a significant portion of a specific word or sentence has already been transmitted. Usually the remote past portion of a message tends to exert little influence on the alphabet characters currently issuing from a message transmitter. In decision making, however, there are generally very few steps in the process which have a degree of "independence" comparable to that of the letters of the alphabet in message relay. The past is of vital importance in decision making, rigidly curtailing the number of alternative courses of action. For example, a decision as to whether 100 or 1,000 units of a given product should be produced next week rests intimately upon what past sales have been and how future sales can be expected to match past performance. Reliance upon empiricism helps reduce the almost limitless range of alternatives to a relatively few highly probable and very desirable courses of action.

This in part explains how the human mind is capable of making complex decisions the solution of which would take considerable programming even on a high-speed computer. Countless short cuts are taken, reducing the number of "calculations" to a bare minimum.

Information theory, by its stress upon the need for compactness and effectiveness in messages, might provide invaluable assistance to the industrial administrator by providing scientific short-cut methods relative to industrial communications and decision making.

COROLLARY 5. Linear Programming

Linear programming is probably the best known of all operations-research terms. It has been called "programming interdependent activities" and a "method for making systematic selection." In essence, it expresses business problems in mathematical form, and specifically in linear equations. Solutions are derived from the simultaneous consideration of all quantifiable variables. These solutions are then ranked as to probability of attainment and degree of desirability. The term *programming* indicates the emphasis placed on planning as contrasted with operations or the execution of plans. Thus linear programming is basically a tool for more effective decision making.

Problems expressed in linear-equation fashion might be visualized as having n variables, defining an n-dimensional space. Somewhere within this space there is a point representing the optimum combination of the n variables. Since each variable is restricted to a specific range, these variables can be pictured as hyperplanes in the geometric model, with all possible solutions being restricted to one side of the hyperplane. As more and more variables are introduced and related hyperplanes are projected, the area of solution bounded by the hypersurfaces assumes the proportions of a convex polyhedron in this hyperspace.

In this geometric-model analogy, each variable item is subject to a number of functional restraints. Generally, only two of these functional constraints are considered: the smallest and the largest values of the function for which the hyperplane just touches the polyhedron. Graphic representation would be virtually impossible if every aspect of each function were to be portrayed. Actually, while multidimensional models are valuable for experimental purposes, their complexity limits their industrial application. Obviously, increasing the variables and the corresponding hypersurfaces beyond three or four in number makes graphic or visual presentation of programming extremely complex and of doubtful value to any but the mathematician.

Currently there are many techniques labeled linear programming

in the experimental phase but only a few that have actually been employed to resolve industrial problems. The three best-known methods are:

1. The modified distribution, or MODI, method
2. The simplex method
3. The index method

Only the first two methods will be described since they represent two widely different approaches to similar problems.

The modified distribution method (MODI) is a relatively easy technique because most of the calculations can be done by inspection. All the data are expressed in a common denominator such as standard man-hours, standard machine-hours, processing costs, etc. Having converted all the data into the standard units, the pertinent information is arrayed in block fashion with the least-cost (or maximum-profit) situation being assigned to the upper-left-hand block. All other combinations are arrayed in decreasing order downward and to the right. By a relatively simple process of analyzing differentials between adjacent blocks, the analyst can readily spot the optimum combinations. The advantage of the MODI method is its simplicity. Although the computations can be expressed in mathematical form, the emphasis on tabular presentation minimizes the need for complex analysis.

The simplex method, devised by George Dantzig in 1951, is probably the most widely used linear-programming technique.

In substance the simplex method requires:

1. An objective stated mathematically
2. A set of restrictions

A rather elementary illustration, as set forth in *Linear Programming: The Solution of Refinery Problems,* proposes that:[2]

$$
\begin{aligned}
X_1 &= \text{amount of product we will sell,}\\
X_2 &= \text{amount of product we will not sell,}\\
100 &= \text{maximum capacity for selling product,}\\
\$2 &= \text{unit profit for selling product.}
\end{aligned}
$$

Our objective is to make the maximum profit

$$Z = 2X_1 \text{ (max)}$$

and our restriction is the selling capacity

$$X_1 + X_2 = 100.$$

We also require that X_1 and X_2 not be negative:

$$X_1 \geq 0; \quad X_2 \geq 0.$$

[2] Gifford H. Symonds, *Linear Programming: The Solution of Refinery Problems,* Esso Standard Oil Co., New York, 1955, pp. 1–3.

The solution, of course, is obvious with only a one-dimensional system. Thus

$$X_1 = 100$$
$$X_2 = 0$$
$$Z = \$200$$

and

The solution mechanism by linear programming is as follows:

Step 1	State restrictions	$X_1 + X_2 = 100 \qquad (X_i \geq 0).$
Step 2	State objective	$Z = 2X_1$ (max)
Step 3	Determine null case, let	$X_1 = 0.$
	Therefore	$X_2 = 100 = X_1 + X_2$
	and	$Z = 0 = -2X_1 + Z.$
Step 4	Determine improvement	$\Delta Z/\Delta X_1 = 2.$
Step 5	Make substitution, let	$X_2 = 0.$
	Therefore	$X_1 = 100 = X_1 + X_2$
	and	$Z = 200 = 2X_2 + Z.$

No further improvement in the objective is possible in this case, and an optimal solution is reached. For such a simple case no mathematical formulation is needed, but for the usual problem with many restrictions and a complicated objective function, the method of linear programming may offer the most efficient solution.

In order to apply linear programming to a problem, it is necessary to state the relationships between the variables as a set of linear equations. The variables must be otherwise independent and must exceed the number of equations. Thus, mathematically,

$$\Sigma_j a_{ij} X_j = b_i \qquad (i = 1, 2, \cdots, m; j = 1, 2, \cdots, n; n > m)$$

where the sum of the coefficient a_{ij} times the value of each variable X_j equals a requirement b_i in the ith equation. These equations are the familiar simultaneous equations such as those used in blending problems. An important difference, of course, is the requirement that the number of variables must exceed the number of equations so that an infinite number of solutions can be obtained and the best one selected. Another requirement is that no quantity can be negative. Thus, mathematically,

$$X_j \geq 0 \qquad \text{and} \qquad b_i \geq 0$$

This requirement will assure that only useful answers will be considered.

The solution of the problem by linear programming also requires a directing force or objective which will be maximized (or minimized) during the solution. This is stated mathematically

$$\Sigma_j c_j X_j = \max$$

where c_j is the profit (or cost) per unit of X_j used. The solution is carried out by an iterative process, which at each stage of calculation assigns either zero or positive values to all X_j variables. These values will meet the con-

straints of the linear equations and will tend to increase the maximizing function at each stage of calculation. If a solution is possible, a maximum profit case will definitely be reached and other cases with lower profit can also be evaluated.

The preceding is a relatively simple example. In the more typical situations there are generally more variables and more complex equations. Very frequently the data are expressed in a tabular form known as a tableau, or matrix table. In such a matrix table the number of rows and columns, determined by the number of variables and equations, provides dimensions for the table. The proportions of this matrix table largely determine the time and effort required for solution. For example,[8]

A 25 by 50 matrix can be solved on a desk computer in about four hours per iteration. Solution of the same problem on the IBM 604 multiplier requires about one hour per iteration and on the CPC it is estimated that 25 to 30 minutes per iteration would be required. However, the greatest efficiency may be obtained by using the IBM general solution of the simplex method on its 701 Computer which would require only about 30 seconds per iteration for the 25 by 50 matrix problem. The maximum size simplex method problem currently programmed by IBM is a 50 by 100 matrix.

While linear programming has captured the imagination of many industrial managers, it is important to note some of its limitations as recognized by leading exponents of mathematical analysis. Among the more important mathematical limitations are the postulates of (1) linearity, (2) divisibility, (3) additivity, and (4) finiteness. In addition, there are the obstacles of (1) the computational costs, (2) the difficulty of converting certain variables into measurable terms, (3) the complexity of technique and terminology which makes much of the mathematical analysis incomprehensible to the layman. While these obstacles are serious, they are not insurmountable. With further research in this sphere, it is highly probable that additional major contributions to industrial decision making will be forthcoming.

SIGNIFICANCE

This chapter might understandably have been called "Decision Making through Quantification." Even though many of the factors pertinent to industrial decision making are subjective or intangible in character, it is still imperative to translate all terms into measurable units. Lacking this postulate, decision making becomes, at best, speculation or intuitive action. If this premise is accepted, then the need for quantitative analysis becomes apparent. Once all pertinent factors,

[8] *Ibid.*, p. 3.

constants and variables, have been ascribed numerical or symbolic values, the decision maker can more readily correlate causes and effects.

This stress on quantification, measurement, and correlation has made mandatory the use of mathematical techniques in the sphere of industrial administration. In turn, with improvements in measuring methods, the manager becomes more competent and more confident in calculating risks and making rational decisions. Both prediction and control are obviously improved.

There can be very little question as to the validity of mathematical analysis in industrial decision making. However, some caution should be exercised in the indiscriminate application of mathematical tools to all types of industrial problems. Many of the production and distribution situations are relatively insignificant from a cost-and-contribution point of view. Embarking on an elaborate program of mathematical management would distinctly be out of proportion in such cases. While it has been suggested a short time ago that even subjective factors be ascribed quantitative values, such values should obviously be of the "range" rather than the "point" type. Too narrow or too rigid an assaying in numerical terms of a single subjective factor can easily lead to the discrediting of the entire process of quantitative analysis. More vital than the actual ascribing of numerical values for specific subjective forces is the development of a frame of mind, a way of thinking by the administrator which almost automatically leads to his application of logic, symmetry, proportion, substantiveness, and correlation of cause and effect in every situation involving subjective factors. It is this mental categorizing, this ranking of components and effects on the basis of fact, which differentiates systematic management and particularly scientific management from the wasteful practice of management by fiat, by fancy, or by fatalistic resignation.

As a final note of caution, it should be emphasized that the judicious manager must be competent to determine the degree to which the more complex tools of science and logic should be applied in specific situations. Excessive use of equations, formulas, charts, and related media of quantitative analysis can lead to academic affectation, pedantry, and time-consuming exercises in mathematical magic. The judicious manager must recognize that these techniques are neither infallible nor immutable, nor are they substitutes for thinking. They are merely aids to administrative action and are not goals in themselves. The judicious manager, on the other hand, must be prompt and willing to accept the contribution of these newfangled notions whenever their value has been demonstrated. A changeover from traditional practice usually requires foresight, technical competency, and courage.

ILLUSTRATION 1. The Walking-dragline Case[4]

Fortune recently presented a very interesting illustration of how the best rate for mining by walking dragline could be determined by the use of mathematical models. This version of operations research was applied at an International Minerals and Chemicals Corporation's phosphate-rock strip mine in Florida. Previously, mining procedures had been decided by traditional rule-of-thumb methods. In the new operations-research approach, a team of two experts from Dunlap and Associates, Stamford, Connecticut, made systematic observations and identified 25 distinct parameters, or variable operating factors, involved in the walking-dragline performance. With assistance from the supervisors and the workmen, the operations-research team reduced the number of important parameters to 10, including depth of matrix, depth of overburden, width of strip excavated, location of wells, path of excavation, duration of excavating stand, location of dam line, angle of cut, angle of swing, and length of dragline walk. Changes in any of these parameters would, obviously, affect the optimum in operations. Some factors, such as bucket capacity, length of boom, walking speed, time required to move bucket, setup time, etc., were assumed to remain constant.

In conventional mining, the mine bosses rely on experience and judgment when selecting the presumably best combination of factors. The probability that all desirable combinations will be considered is evidently not very high. However, mathematical model building, although complex and costly, appears to offer a scientific approach as a substitute for long-entrenched systematic-empiric rule-of-thumb decisions.

In this particular case, the operations-research team built a set of equations including the 10 most important variable factors. Pertinent information was coded and fed into a high-speed computer. Performed with pencil and paper, it was estimated that this particular problem would have taken at least 200 man-years. Using the high-speed computers, a series of solutions was made available in less than 2 months. After verifying several sample observations and determining that the solutions were within the range of permissible error, the solutions were translated into a series of tables and charts. From this point on, the operations supervisor could merely refer to these tables and charts and decide upon the optimum operating design. Variations in any of the 10 important parameters could be properly taken care of without recourse to exhaustive calculations.

[4] Herbert Solow, "Operations Research Is in Business," *Fortune*, February, 1956, pp. 130–131.

This particular problem was economically feasible because the giant Bucyrus-Erie dragline, with a capacity of 1,500 tons per hour, cost about $1,250,000. Each minute of down time on a one-shift basis resulted in a loss of $20 in sales and a lost overhead charge, on a one-shift basis, of at least $3 per minute. The work's repetitiveness and the huge volume of material handled presented an ideal operations-research situation. The results of this study suggested that the optimum yield should come to about 958 cubic yards of ore hourly. This rate would yield a theoretical gain of 70 per cent in dragline operating efficiency. Although disruptive factors might hinder attainment of the maximum theoretical gain, even a modest improvement in efficiency would warrant the cost of the mathematical modelmaking.

QUESTIONS

1. In what respect does this problem solution by mathematical means resemble Frederick Taylor's experimentation?
2. Are there any significant differences between the operations-research method and Taylor's experiments?
3. What are the practical limitations to the more extensive application of this form of industrial problem solving?
4. What exaggerations can you spot in the statement that the solution of this problem by conventional techniques would have required 200 man-years of calculation?

ILLUSTRATION 2. Programming Procedure

The objective of this illustration is to show the logic underlying the use of mathematical techniques, and linear equations in particular, in the solution of simple production problems.

A specific lathe department has three machines, a 12-30 Duplex Miller, a 5-54 Single Ram Vertical Broach, and a 2-72 Automatic Rise and Fall Miller, suitable for the milling operations which are requisite to products *A* and *B*. The machines, labeled *X*, *Y*, and *Z*, respectively, have the following unit processing costs and weekly capacities:

Machine	Capacity		Unit processing costs	
	A	*B*	*A*	*B*
X	85	100	$10	$6
Y	60	150	$12	$4
Z	50	160	$13	$4
Total	195	410		

From the preceding data, it is obvious that machine X has output and cost advantages in the processing of product A. Machines Y and Z, while they entail identical unit processing costs for product B, do not have the same capacities. Thus machine Z is best suited for the volume production of product B, while machine Y occupies a residual position in respect to both products.

If all three machines are set to work upon product A, 195 units should be produced at a total processing cost of $(85 \times \$10) + (60 \times \$12) + (50 \times \$13)$, or \$2,220. This represents an average processing cost of \$2,220/195, or \$11.28 per unit. Similarly, if the three machines are scheduled on product B, output should reach 410 units. Total costs would amount to $(100 \times \$6) + (150 \times \$4) + (160 \times \$4) = \$1{,}840$. In this case, average unit costs would equal \$1,840/410, or \$4.49.

Assuming that in a certain week orders were to be processed for 115 units of A and 190 units of B, it seems evident that machines X and Z, because of operating advantages, should work exclusively on products A and B, respectively. The balance of the orders would logically be assigned to machine Y.

This type of scheduling does not entail any complex computations since the terms are few in number and potentials are drastically limited. Nevertheless, the reasoning process by which this allocation is effected is typical of cases where complex calculations are in order. In every instance the essentials include quantification, symbolization, expression in linear equations, and calculation to determine the optimum equation. Quantities are estimated on the basis of some acceptable norm such as experience or engineering analysis. Symbolization can be effected in numerous ways. In this instance the letters X, Y, and Z are used to designate the machines while subscripts define outputs and costs attributable to the respective machines. Thus Xa_1 could represent machine X working full time on product A with a weekly output of 85 units. Xa_1c_1 could be used to designate the total costs in such a case. Thus $Xa_1c_1 = 85 \times \$10 = \$850$, total costs using machine X for an entire week processing item A. Similarly, Ya_2c_2 could represent machine Y working full time on product A. Then $Ya_2c_2 = 60 \times \$12 = \$720$, total costs of producing 60 units of product A (one full week's capacity). This procedure would yield the following equation, which shows the total cost of producing 195 units of A using the full capacities of machines X, Y, and Z for an entire week:

$$\begin{aligned} Xa_1c_1 + Ya_2c_2 + Za_3c_3 &= (85 \times \$10) + (60 \times \$12) + (50 \times \$13) \\ &= \$2{,}220 \end{aligned}$$

Comparable equations can be devised for any combination involving modifications in machine capacities, specific products, and processing

costs. Since the subscripts 1, 2, 3, referring to unit costs, are associated with product *A*, another series of subscripts, such as 4, 5, 6, could adequately designate the processing costs appropriate to machines *X*, *Y*, and *Z*, respectively, in making product *B*. The same procedure permits symbolization and rapid identification of even the slightest modifications in parameters.

Optimum results in this particular problem, 115 units of *A* plus 190 units of *B*, would be depicted thus:

$$Xa_1c_1 + 0.5Ya_2c_2 + 0.2Yb_2c_5 + Zb_3c_6$$

This equation could be translated to read:

1. The full capacity of machine *X* should be used to make product *A* at a total cost of $85 \times \$10 = \$850$.

2. One-half the capacity of machine *Y* should be allocated to product *A*, and one-fifth to product *B*. The remaining three-tenths of machine *Y*'s capacity would not be utilized. Costs would be computed as

$$1/2(60 \times \$12) + 1/5(150 \times \$4) = \$360 + \$120 = \$480$$

3. The full capacity of machine *Z* should be employed on product *B* at a total cost of $160 \times \$4 = \$640$.

4. Total cost to produce 115 units of $A = \$850 + \$360 = \$1{,}210$.
   Total costs to make 190 units of $B = \$120 + \$640 = \$760$.

5. The product of this equation is equal to $\$1{,}210 + \$760 = \$1{,}970$. This represents the lowest possible cost, under prevailing conditions, of manufacturing 115 units of *A* and 190 units of *B*. Any other combination, such as $0.7Xa_1c_1 + 0.3Xb_1c_4 + 0.9Ya_2c_2 + Zb_3c_6$, would yield higher total costs. The preceding equation would necessitate expenditure of approximately $1,260 for product *A* and $820 for product *B*. The inference is obvious.

QUESTIONS

1. Demonstrate arithmetically how the introduction of additional machines, new products, changes in capacity, and modifications in processing costs will increase the complexity of pertinent equations.
2. Translate the following weekly production orders into optimum-machine-utilization equations:
   a. 160 units of *A* and 15 units of *B*.
   b. 30 units of *A* and 300 units of *B*.
   c. 60 units of *A* and 40 units of *B*.
3. What are the total processing costs in each instance?
4. What are the advantages and limitations of this approach to decision making?

ILLUSTRATION 3. The Production Equation

An ingenious approach in the direction of quantitative analysis of management problems was made at least a decade before operations

research was popularized by Dr. Paul Douglas of the University of Chicago, later several-term United States Senator from Illinois. His probing into the question of equitable distribution of income shares led to the development of a production equation. In general, the equation is written in a form similar to $P = f(x_1, x_2, \ldots, x_n)$, where P is the resultant of the factors $x, x_1, \ldots, x_n$, with f indicating the connection between the product and the agents. If only two factors are involved, for example factors L and C, then $P = f(L,C)$. Among the best-known versions of the production equation is the form $P = bL^kC^{1-k}$, where k measures the percentage of increase in the output associated with a 1 per cent increase in the quantity of factor L, with factor C remaining constant.

Senator Douglas's objective was to discover what, if any, relationship existed between variations in the productive factors, and specifically labor and capital, together with changes in productivity. His contribution, while momentous in itself, was limited because of the great number of variables affecting productivity and because of the complexities entailed in mass-data processing without adequate electronic equipment. No high-speed computers were as yet available for the tedious preliminary operations. Nevertheless, Dr. Douglas's experiment and similar pioneering ventures challenged the imagination of industrial managers seeking a quantitative base for more effective decision making.

QUESTIONS

1. Could the production equation be termed a forerunner of operations research?
2. Would it be feasible to portray our economic system graphically showing each of the pertinent variables as constraining hypersurfaces of a polyhedron?
3. What very practical inferences could be made from a valid expression of the production equation?

ILLUSTRATION 4. "Bizmac's Batting Averages"[5]

Speaking of predictions, the new electronic computers are apparently as fallible as human soothsayers. It may be recalled that when R.C.A. installed one of its $4-million Bizmac computers in the Detroit Army Ordnance Tank-Automotive Command headquarters, R.C.A. threw a party for the press and put on a demonstration of Bizmac's prowess. R.C.A. scientists fed the machine a great deal of background data and "told" it the batting averages of top major leaguers during the previous five seasons. Working from these data, the machine made 200 algebraic computations for each player, a process that

[5] *Fortune,* November, 1957, p. 128.

took just two seconds, and then came up with its predictions of 1957 batting averages. These are listed herewith, along with the players' actual averages:

	Forecast	Actual
Mickey Mantle	.342	.365
Richie Ashburn	.328	.297
Ted Williams	.322	.388
Harvey Kuenn	.319	.277
Minnie Minoso	.317	.309
Carl Furillo	.314	.307
Ray Boone	.313	.273
Nelson Fox	.309	.317
Stan Musial	.305	.351
Ted Kluszewski	.304	.268
Duke Snider	.302	.274
Yogi Berra	.297	.251

Perhaps the explanation of the machine's dismal showing is, as its name suggests, that it was intended to be a business machine, not a sports expert. Let us suggest, then, that Bizmac steer clear of baseball and stick to business.

QUESTIONS

1. In mathematical terms, about what degree of accuracy in prediction did Bizmac attain in this instance?
2. What factors might have limited prediction in this case?
3. Can you suggest some improvements in measuring technique so that similar ventures might yield better results in the future?

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CHAPTER 9

Corporate Control

DEFINITION AND DESCRIPTION

The basic management functions of decision making and decision implementation have been thoroughly discussed in the previous chapters and specifically in Chapters 7 and 8. In these presentations it was emphasized that the satisfactory fulfillment of management functions requires an adequate measure of control. In this context control can be defined as the power to demand services from an organization's members. This power consists in the right to give instructions, advice, and commands, the right to insist on conformity of performance to prescribed norms, the right to use sanctions when deemed necessary, and the right to modify the course of action when expediency dictates. Obviously, there is a tremendous heterogeneity as to types, degrees, and levels of control. For example, the issuance of simple instructions relative to a routine operation differs radically from the control inherent in policy making. The many nuances, or subtle variations in the meaning and degree of control exercised in industry, complicate analysis. The following classification is at best a rather arbitrary and general differentiation of the three major *levels* of administrative control.

1. Ultimate control is vested in the owners of the enterprise. In the modern large-scale corporation the geographic dispersion of the stockholders and their apathy toward corporate affairs generally results in the assumption of a passive attitude by this group. Except for relatively infrequent outbursts of indignation, particularly when dividends

dwindle, the stockholders of large corporations are content to let their duly elected representatives, the directors, prescribe policies and procedures.

This arrangement is not typical of small business, where the owners frequently take a more direct interest in the management of company affairs. However, when the owners do manifest this keen interest, they perform in several capacities, exercising not only ultimate control but also intermediate and immediate control.

2. *Intermediate control* generally rests with the board of directors or with some comparable group. The divorcement of ownership and control in large-scale enterprise creates a need for a trusteeship whose primary function is to protect the owners' interests. As a rule, the board of directors exercises active control as to major policies, but only a passive control over minor policies and over actual operations.

3. *Immediate control* is invariably exercised by the ranking corporate officials stationed at the scene of operations. It is these individuals who have the responsibility of carrying out the accepted policies, plans, and procedures. In most large-scale corporations immediate control is the responsibility of the executive group of managers. There is considerable diversity in these executive groups as to size, composition, and function.

In some instances immediate control is centralized in the top executive. This is particularly the case where the top executive is either the owner of the enterprise or an extremely domineering individual. More frequently even a very dynamic, competent, and would-be-autocratic top executive must reckon with power cliques among his most immediate corporate associates. In the more progressive large-scale manufacturing enterprises, there seems to be a very definite trend toward a decentralization of immediate control along both geographical and functional lines. Such decentralization frequently leads to a group approach in the exercising of immediate control. This group approach will be further considered specifically as to the function and effectiveness of committees in respect to decision making and immediate control in industry.

The preceding classification pertains to the three major *levels* of control found in all large industrial organizations. In addition to these levels of control, it is important to differentiate among the more important *types* of control. The following descriptions consider only the four most prevalent types of control.

1. *Entrepreneur-Manager.* As long as the scale of enterprise is relatively small, the three basic levels of control (ultimate, intermediate, and immediate) can be concentrated effectively in one person. This is

particularly the case where the organization is still operated by the founder or by an immediate heir possessing a high level of managerial ability. By far the best-known illustration of this type of control by an organizational jack-of-all-trades was provided by Henry Ford, Sr. In addition to his mechanical genius, the founder of the Ford Motor Company also displayed remarkable managerial ability. Despite criticism leveled at Ford's one-man control and his eccentricities as to managerial practice, the phenomenal growth of the Ford Company during his tenure is the strongest refutation of such critics. There are still numerous examples of this type of control although its heyday occurred about a half century ago.

2. *Owner-Director.* With increased scale of enterprise and with greater complexity in production processes and in methods of distribution, it is logical that many of the managerial functions previously performed by the entrepreneur-manager should be delegated to hired assistants. Such delegation permits the owner to dedicate his energy to the more important problems: those dealing with the ultimate and intermediate levels of control. This type of control can be used satisfactorily as long as the executive group does not object to its hired-hand status. However, as the executive's position acquires greater importance, there is a decided tendency for the executive to seek some voice in the determination of top-level policy. Eventually this becomes an aspiration of the entire executive group. Organizational strains and stresses inevitably appear if this demand is ignored. As a consequence there is an inclination on the part of many owner-directors to adopt one of the following two types of control.

3. *Outside Directors.* This type of control is very common in certain segments of American industry. It is characterized by a board of directors whose members do not actively participate in the execution of policy or in the performance of corporate functions. Such board members are concerned only with the formulation of top-level policies. As a rule, outside directors are selected on the basis of their public prominence, their importance as customers, or their association with financial institutions which have a sizable equity or lending interest in the corporation in question. In the latter capacity, it might be said that outside directors act as trustees, protecting the investment of the financial institution's many depositors. Even the public figures who assume outside directorships perform in a trusteeship capacity since they presumably have the public good paramount in their interests.

On the other hand, it must be stressed that outside directors usually have relatively insignificant personal stockholdings in the corporations they control. Recognition of this fact is important since it is too fre-

quently assumed that outside directors are simply exercising the right to control the use of property to which they have title. At best, an outside director is a guardian of other people's interests. As long as the guardian diligently fulfills his responsibilities, there is minimum cause for complaint. However, when a financier or public figure assumes multiple outside directorships, a serious suspicion arises concerning the ability of the individual to do a diligent job in such multiple roles. In some cases the number of outside directorships held by one person reaches such proportions that it is doubtful if the director knows much more about the corporations than the names and basic activities. For example, Hulett Clinton Merritt, who died in 1956 at the age of 83, had been a director of at least 138 different companies. In 1929, J. P. Morgan and his 17 partners held 99 directorships in 72 different corporations whose combined assets totaled more than $20 billion. These directorships included 23 in financial institutions, 47 in industrial corporations, 11 in railroads, and 18 in public utilities. Probably the best-known outside director of recent times is Sidney Weinberg, who, in addition to his regular position as a partner in the investment firm of Goldman, Sachs, has served on approximately 40 different boards. In 1957 Weinberg had curtailed his directorship activities to 11 major positions in the following organizations: Ford Motor Company; General Electric; General Foods; General Cigar; National Dairy Products; Continental Can; B. F. Goodrich; Champion Paper and Fibre; Van Raalte; McKesson and Robbins; and Cluet, Peabody.

While these illustrations are rather extreme cases, there are numerous examples of outside directors serving on between 5 and 15 different boards of directors. Obviously, this spreading of talent and of time means that the outside director cannot dedicate his full energy to the affairs of a single corporation. Divided loyalties and a lack of comprehension and appreciation of the corporate working milieu can easily lead to an indifferent or marginal performance on the part of outside directors. Absentee directors, like absentee landlords and monarchs, too frequently give their attention to peripheral problems.

4. *Functional, or Inside, Directors.* The functional director is a professional manager who, in addition to serving on the board of directors, also actively heads a specific area or divisional component of the organization. Generally, he has risen from the ranks within the very company whose top-level policies he now helps to formulate. In this respect, the functional directorship is the culmination of a well-developed promotion-from-within policy. Because he is a full-time company employee and because his administrative talent is dedicated exclusively

to the one company, the functional director is more familiarly known as an inside director.

The functional, or inside, director's long tenure with the company generally means that he has become acquainted with most of the company's operational techniques and problems. It is this intensive and extensive background of technical and business experience which particularly fits the professional manager for service on the board of directors. Decision making at the operational level provides the best proving ground for development of high-potential policy makers. Actually, in the modern large-scale enterprise, the logical and most fertile source from which top-level decision makers can be recruited is the next lower level of decision makers—the functional and divisional managers. This election of qualified managers to the board of directors is not exclusively a phenomenon of large-scale enterprise. A growing number of small- and middle-sized concerns have recognized the benefits of functionalization, as is apparent by their acceptance of multiple management and similar variants of "inside" control.

The major objection to functional directors is the belief that this practice invariably leads to inbreeding, to domination by the chief executive, to a subordination of the stockholder's interests, and to an excessively liberal salary and bonus disbursement for the executive directors. While there is probably some validity to such charges, no major substantiating studies have been forthcoming. On the contrary, payments to executives seem to be more closely correlated with the size of the company, its record of earnings, competition for and the relative scarcity of qualified managers, and the competency of the individuals. Similarly, dividend disbursements seem to have less relationship to inside or outside control and more to factors such as the current cost of borrowing, the earning potential, the necessity for expansion of facilities, etc.

Exhibit 9-1 summarizes the relationship between *type* of control

Exhibit 9-1

Type of control	Level of control		
	Ultimate	Intermediate	Immediate
Entrepreneur-Executive	X	X	X
Owner-Director	X	X	
Outside director		X	
Functional director		X	X

and *level* of control. While the entrepreneur-operator performs at all three basic levels of control, the remaining three categories are confined to a single level or to a combination of two. An even more complete analysis would be presented if two additional types of control were included: state socialism and utopian communism. In the former, the state, with title to all productive property, exercises ultimate control in an active manner to a degree which completely subordinates the other levels of control. In utopian communism the two upper levels are incidental to the lowest control level, in a situation where every individual, at least in theory, is an executive.

DEVELOPMENT

The transition from the entrepreneur-executive type of industrial control to the outside and inside versions of corporate directorates is currently the most vital evolutionary aspect pertinent to control in industry. During the past half century the scale of enterprise has expanded tremendously. The functions of production, financing, distribution, and record keeping have become considerably more complex. While there is an occasional exception to the rule, it seems logical to state that the dynamic captain-of-industry type, characteristic of nineteenth-century American industry leadership, has been found woefully lacking for large-scale modern enterprise. There are numerous instances where, even fifty years ago, the need for a new type of control to replace the entrepreneur-executive was apparent. A classic example was Andrew Carnegie's decision to sell his steel companies to a group of financiers headed by J. P. Morgan. The result of this financial maneuver, the United States Steel Corporation, has long been one of the best examples of the retention of passive ultimate control by the stockholders while financiers and other outside directors exercised intermediate control. The execution of policy and the immediate control of operations were assigned to professional managers. This arrangement is typical of the outside-dominated corporation.

A number of the captains of industry, even in relinquishing their active roles, refused to yield control to financial institutions. Such persistence necessitated the retention of ownership either by the entrepreneur, his heirs and friends, or by a public group with holdings so widely dispersed that no single individual or institution could dictate policy. In certain industries, notably those with rapid-growth prospects, financial requirements could be met through a reinvestment of earnings. Then too, the relatively higher profit margins and the glamour of spectacular performance made the floating of stock issues relatively easy. Consequently, there was considerably less need to seek institu-

tional funds and less danger of relinquishing control to outside directors.

One of the strongest moves toward inside control followed the splitting, under pressure of antitrust legislation, of John D. Rockefeller's original Standard Oil Company (New Jersey). The parent company and all the new companies which were formed out of a regrouping of the 33 divorced subsidiaries adopted the inside type of intermediate corporate control. The offshoots of John D. Rockefeller's oil empire are today among the best examples of large-scale enterprises being successfully run by executives who also perform as directors. Another good example is the evolution of the E. I. du Pont de Nemours Corporation from a family type of control to professional manager control. The du Pont example has also had a noticeable effect upon the pattern of control within General Motors Corporation, which is also manager-run.

The evolution toward functionalization and thence to inside control seems to be apparent in a number of the long-time outside-run organizations. For example, General Electric Company currently has 35 vice-presidents, each in charge of a specific geographic or functional component. While this functionalization does not necessarily mean that General Electric is immediately capitulating to inside control, it does indicate that this corporation has recognized the growing importance of professional managers.

The United States Steel Corporation appears to have taken an even more positive step away from outside and toward inside control. Traditionally, the corporation's finance committee, created in 1901 and composed chiefly of outside directors, was all-powerful in making policy. The finance committee, with New York as its headquarters, is also typical of outside control in that it has had almost no immediate contact with manufacturing or distribution. In 1952 the finance committee's powers were severely abridged by the formation of an executive policy committee, composed primarily of manager-directors. This committee, with headquarters in Pittsburgh, the operational center of the company, lays down corporate objectives, does all long-term planning, and makes recommendations to the finance committee. The shift in the locus of intermediate control in United States Steel, from the exclusive jurisdiction by outside directors to somewhat of a compromise type of control, is a radical innovation for this former citadel of outside control. It is interesting to note that U.S. Steel's major competitor, Bethlehem Steel, has long had a board of directors comprised exclusively of the corporation's executives who can, if necessary, convene within a few hours' notice.

In summary, functional or inside directorates appear to be particularly effective where:

1. Ownership is so widespread that the stockholders cannot effectively communicate and form strong interest groups.

2. Widespread ownership makes it difficult for a financial syndicate to acquire a controlling interest.

3. A single individual, a family, or a closely knit group has voting control and rejects "interference" from financial institutions.

4. Financial needs can be met in large part by reinvestment of earnings, through governmental borrowing or through the "easy" sale of additional stock.

5. Technological changes are rapid and significant.

6. The organization is primarily concerned with consumer goods rather than capital goods.

COROLLARY 1. Multiple Management

Multiple management is one of the better-known attempts at devising a satisfactory scheme for worker-owner participation in corporate control. The plan was introduced in McCormick and Company, the world's leading spice and extract producer. The company has approximately 1,300 employees and annual sales of about $50 million. Charles P. McCormick, upon becoming president of the corporation in 1932, set up a junior board of directors in addition to the regular senior board. The new group was made up of 17 members selected from among the salaried personnel. This group, whose composition is modified twice a year by the replacement of three members, functions after the fashion of a full-fledged board of directors. It has its own by-laws, board room, and officers. The members receive a fee for serving on the board. During the past twenty-five years, this innovation has had spectacular results. More than ten thousand suggestions have been considered by the junior board. Nearly all the suggestions approved by this body have in turn been accepted by the senior board. Since the introduction of multiple management, practically every addition to the senior board of directors has been a former member of the junior board. In this respect, multiple management is a device for grooming qualified functional, or inside, directors. The morale-boosting stimulus of such opportunity for advancement to the highest level in the organization is obvious.

Among the tangible results testifying to the success of multiple management in the McCormick Company is the extension of the plan so that presently there are, in addition to the salaried personnel board, comparable groups functioning as a factory board, a sales board, and

an institutional sales board. Other results include a reduction in labor turnover from 33 to 3 per cent, the elimination of time clocks, the complete absence of strikes and similar work stoppages, a fifteenfold increase in sales, and a very positive rejection by the employees of all attempts at unionization. The introduction of multiple management by more than 500 additional firms likewise testifies to the growing popularity of this compromise in corporate control.

One of the cardinal principles of multiple management is that ownership of the organization be vested in management and the workers. Acquisition of sizable stockholdings in the enterprise by outside groups, and particularly by financiers, is assumed to lead to absentee directors and thence to an exaggeration of the profit motive. Such exaggeration is considered deleterious to morale and to effective performance. Consequently, the McCormick Company has taken measures to ensure ownership by actively interested individuals—the managers and the workers. While the McCormick family holdings have dwindled from 90 per cent to about 12 per cent of the voting stock, the workers have gradually acquired a majority of the voting shares. Provisions have been made to perpetuate this owner-worker control through the corporation's by-laws which prohibit the sale of voting stock to outsiders.

While multiple management has been depicted as a successful top-level control device, there seems to be serious limitations to its widespread adoption. No large-scale enterprises and very few medium-sized concerns have accepted the plan. Both trade unions and trade associations have indicated their opposition. The paternalistic aspects have attracted unfavorable attention. The making of decisions by the junior boards has been viewed as a subtle device for getting practically free directorship services from functional experts while the senior directors shirk their responsibilities. Even the semblance of success as manifest in the McCormick Company has been attributed to extraneous factors such as the character of the spice business and the over-all progress in our economy.

Regardless of the pros and cons, however, it must be conceded that multiple management has made a contribution to the solution of labor-management tensions. Its importance to the better comprehension of corporate control seems apparent. Multiple management reduces the significance of ultimate control by placing it in the manager and worker groups. The allocation of intermediate control to company-men directors, many of whom have risen from the wage-earner category, minimizes the friction which so easily arises when important executives are excluded from the board of directors. However, the juncture of intermediate and immediate control, in addition to possessing all the

advantages of inside control, has in this instance additional disadvantages. To the semblance of paternalism, there is added the danger that gifted individuals, particularly at the executive level, might not get adequate inducement to perform at maximum. Furthermore, a serious recession could disillusion the worker-stockholders. Despite its successful application for more than twenty-five years by the McCormick Company and other equally enthusiastic proponents, there is serious question as to the universal application of this form of industrial control.

COROLLARY 2. *Mitbestimmungsrecht*

This sesquipedalian term, meaning the right of codetermination, has serious implications relative to the concept of control in industry. Codetermination is a refutation of the generally accepted premise that ownership alone has the prerogative of determining a business organization's course of action. Critics of codetermination label this concept a direct step toward socialism. Under socialism, the means of production are owned by the state. Government-appointed managers supervise the corporate affairs in the interest of the Federal government. Under *mitbestimmungsrecht,* or codetermination, the right to make top-level decisions is vested in a board of directors composed of representatives of stockholders, management, and labor unions.

The trend toward codetermination, initiated in Germany, was accentuated by the favorable attitude of the post–World War II occupying powers. The British, who at that time had a labor-run government, were especially partial to the establishment of joint management-labor supervisory councils in their zone, which included the Ruhr. In 1945 the occupying powers permitted the reviving of the workers' councils, authorized by a 1920 German law. In 1947 the Ruhr's steel mills and coal mines were required to set up joint management-labor supervisory councils. By 1951 German labor unions succeeded in having an even broader codetermination law passed. This law gave the unions the right to name five members of the standard eleven-man board of directors in each of the nation's coal and steel enterprises. Five directors were to be named by the stockholders, and the eleventh board member was to be elected by the other ten. In addition, the director of personnel was to be a union member. One year later, a modification of this law provided for a one-third union representation on the directorates of all companies with 500 or more employees. Management and stockholders were each to elect one-third of the board members. In companies employing between 100 and 500, workers' councils were to be informed on all important decisions pertaining to such topics as sales,

financing, profits, new products, etc. These councils were also given the right to regulate hiring and firing. Decisions relative to modifications in plant and equipment likewise had to have the sanction of the workers' councils. Even in the very small concerns, those with less than 20 employees, work councils were given the right to handle labor contracts, employee grievances, training, and welfare. The only organizations exempt from the codetermination law were schools, churches, and newspapers, where presumably such control might constrict freedom of thought.

Proponents of codetermination contend that participation by labor representatives in corporate policy formulation is conducive to effective organization. German unionists point out that in the recent postwar era, the workers were frequently called upon to forgo seeking wage increases in order to better German industry's position in the world markets. Labor leaders indicated their willingness to place the nation's welfare ahead of immediate economic gains, but only on the condition that labor be given a voice in determining corporate policy.

It should also be pointed out that ownership of European industry is, as a rule, far more concentrated than in the United States. Owner-managers are also relatively more prevalent. Separation of ownership and control, such as has occurred in the United States during the past half century, is not even remotely approximated in European industry. Thus, it is argued, codetermination provides a much needed system of checks and balances whereby a single factor of production—ownership—will be prevented from exerting autocratic power in industry. Proponents of the theory point with some justification to the strike-free record of German industry in contrast to the relatively more frequent work stoppages characteristic of British, French, and American industry. The remarkable climb in the productivity curve in German industry might also be attributed in part to the introduction of codetermination. The upsurge in German productivity has far surpassed even the most optimistic of the early postwar predictions.

Conversely, inclusion of labor within the industrial policy-making group removes a countervailing force presumably requisite to industrial dynamism. The juncture of labor leaders, owners, and managers can easily be construed as collusion, invariably leading to the detriment of the consumer. Lacking a competitive balance of power among the major factors of production, the economic system assumes a planned rather than a free-enterprise character. Whether this is desirable is currently largely a matter of opinion. The innovation is so recent that a fair appraisal cannot be made until more information as to codetermination's success or failure can be acquired. Regardless of

one's sentiments on this score, the concept has injected many aspects alien to the generally accepted concept of industrial control.

COROLLARY 3. Committees

The function of committees in industry is subject to considerable controversy. An extreme group of proponents looks upon this very popular device as the epitome of democracy in industry. Through this voluntary pooling of human resources, it is claimed, the organization can more readily attain its maximum productive potential. Committee critics, on the other hand, view this system as a bureaucratic device for executive buck passing. As with all controversial issues, there is probably some merit and considerable exaggeration in the contentions of both groups of extremists.

By definition, a committee is a group of competent and interested persons pooling their thoughts and actions in the facilitation of the decision-making process. Although they differ in respect to purpose, composition, structure, operating procedure, measure of authority, etc., there are basically three types of committees: (1) investigatory, (2) advisory, and (3) executive-judicial.

1. Investigatory. These committees are generally charged with gathering information pertinent to a specific problem. Such information can be used as the basis for decision making by an individual possessing the proper authority. In other instances, these facts might be made part of an educational endeavor. Then too, as happens in very many cases, the accumulation of data can simply be filed and forgotten.

2. Advisory. The increasing technological complexity in modern industry makes it mandatory that decision makers seek advice from their functional assistants. The growing seriousness of the consequences which result from poor decisions and the increasing complexity of functional interrelationships make the committee technique particularly useful in this advising phase. However, it must be remembered that in every instance the pooled judgment of the committee is merely offered as advice. In the last analysis, it is the individual to whose position is attached the authority or jurisdiction pertinent to the specific problem and who is held responsible for the decision rendered.

3. Executive-Judicial. The use of committees as tribunals, particularly in the rendering of legal decisions, dates back to antiquity. A tribunal in this context is a group of authorized people who must jointly render a binding decision. No single individual of this tribunal is individually responsible for the decision, even though a senior member, such as a chief justice or chairman, might be the communicator of the decision. This equal allocation of joint authority and joint respon-

sibility is based on the premise that these special committees are functioning as legitimate representatives of the group.

The same principle has been used for a very long time at the top level of industry. The board of directors is simply a tribunal, a committee of trustees duly designated by the owners, to enunciate executive-judicial pronouncements in the name of the stockholders.

The use of executive-judicial types of committees at lower levels is of comparatively recent origin, considering that, in industry as in military organization, staffs, councils, committees, and similar groups have invariably provided advice rather than formal decisions and the execution of these decisions. This trend toward the use of committees within industry for the formulation of binding policies, plans, and procedures might indicate an important change in the philosophy of industrial organization.

Much of the misunderstanding as to the function of committees stems from their indiscriminate use. To many an unqualified administrator this is an easy way out of perplexing problems. Under the guise of democratization, the weak administrator in effect abdicates his authority by his too eager sloughing off of responsibility. It must be emphasized that such attempts at responsibility evasion represent serious violations of the basic management precept that ultimate authority and ultimate responsibility can never be delegated. This condemnation of the attempts of incompetent leaders to shove responsibility upon subordinates is not to be construed as an indictment of executive-judicial committees. Since, as has already been mentioned, the board of directors performs as an executive-judicial committee, it seems logical to believe that the same pattern can, under certain circumstances, be successfully applied at lower levels.

Advantages of Committees. Probably the most important contribution of committees is their use as a system of checks and balances. Unilateral action is kept at a minimum. This tends to restrict the giving of preferential treatment to vested- and special-interest groups. The process of group decision making is conducive to compromise and to voluntary acceptance. It is a deterrent to hasty action. Not only is the decision more readily accepted, but its dissemination is greatly facilitated. Finally, this pooling of ideas and judgments is productive of new ideas.

Disadvantages. Most of the reasons set forth as advantages of the committee technique also have certain negative aspects. For example, not only is the system a deterrent to hasty action, it can easily become an excuse for procrastination. While new ideas supposedly flow from this group interaction, it must be remembered that creative effort is

almost entirely the province of the individual. Every major contribution to civilization has been the product of individual thinking. At best, brainstorming and similar group effort produce a revamping of old ideas rather than a genesis of new thoughts. Compromising, which is typical of all committees, is also not necessarily a boon to effective organization since the yielding by the parties concerned generates ill will. Probably the strongest argument is the excessive cost of committees as compared with results. In most instances a competent administrator, with the aid of able functional assistants, can easily outperform the average committee.

Structure of Committees. Whether it is advantageous to use the committee approach or not depends very much upon how a committee is set up, its purpose, and its operating procedure. Too small a committee can result in the loss of all the benefits of group action. Contrariwise, too large a committee becomes unmanageable and ineffective. As can be inferred from the principle of the span of control, complexities increase geometrically with increased group size. It is also important that a committee be made up of individuals with different points of view, different backgrounds, and varied but compatible temperaments. The chairman must be a veritable Solomon. The listings of attributes requisite for successful committee chairmanship invariably include every known virtue. In particular, the chairman must know when to broach a topic and when to put an end to deliberation. Although possessing a measure of veto power, recourse to arbitrary action must be very infrequent. He must referee personality clashes and draw the best out of the varied members of the group.

In summary, a committee is only as good as its constituents. It is a very useful tool under certain circumstances, yet in many cases it becomes a serious impediment to organizational effectiveness. It must always be kept in mind that committees are extremely weak in the exercise of control. Even when committees do a particularly good job in gathering facts, advising, or formulating decisions, the results of such action are contingent upon proper execution. Unless the executives and managers can be induced to follow through with the committee's recommendations and decisions, it is highly doubtful that the results will even approach the expectation. In any event, the relatively high costs of the committee technique should act as a restraining force to its indiscriminate use.

COROLLARY 4. Divisionalization—Profit Centers

This term refers to the organizational structure in which semiautonomous divisions operate within a framework of policies, plans,

and procedures determined by the central management. In this context, divisionalization pertains to the concept of centralization, which was broached in corollary 2 and illustration 2, Chapter 5. Our concern at this point is primarily with the consequences of centralization in respect to organizational control.

Following General Motors' classic experiment at decentralizing operations while centralizing staff activities, numerous proponents have initiated comparable plans. The term *profit center* has become widely accepted to designate a semiautonomous division or department which is individually responsible for demonstration of its profitability. This onus implies a high degree of decentralization since each component must maintain its own profit-and-loss statement. A considerable degree of financial independence, accurate yardsticks for measuring the unit's performance, and almost complete freedom in planning and operations are integral to the profit-center concept. Separation of each profit center's capital, sales, costs, and profits sets up each of these units as a quasi subsidiary. Major policy making, however, is concentrated in a central agency. Competition among profit centers is encouraged. Rivalry sometimes reaches a pitch comparable to that which would be expected of totally independent concerns within a highly competitive market. Since every profit center becomes a measurable segment of the parent company, accountability can easily be vested in the head of each unit.

The advantages of allocating greater responsibility and authority to profit centers is apparent. The strongest favorable testimony comes from the tremendous popularity of this method of corporate control. For example, Westinghouse converted from a functional to a divisionalized form of organization in 1935. Within the next quarter century the company expanded to nearly eight times its size at the inception of divisionalization. This rapid expansion necessitated further subdivision. For example, the lamp division ultimately had to be broken down into five major-product departments, each responsible for all phases of its business, including engineering, manufacturing, and sales. As one result of expanded scale of enterprise, Westinghouse now has 65 product divisions and departments, each a profit center.

General Electric is another staunch proponent of divisionalization despite its relatively late adoption of the concept. Prior to 1951 GE was the epitome of strong, centralized control. In the reorganization following Ralph J. Cordiner's assumption of the presidency, GE moved swiftly into an adoption of the profit-center concept. Currently there are 118 operating departments in the company. These are combined into 22 divisions, which in turn make up four major operating groups

and one distribution group. The departments and not the divisions, groups, or headquarters are the basic components of control within GE. Each of the 118 operating departments is vested with profit responsibility and operating authority. Centralized policy making is achieved through the office of the president, which designates a committee comprising the company chairman, president, and five key vice-presidents.

General Motors' contribution in developing the concept of divisionalization has already been mentioned. In the GM plan, its 35 divisions have freedom to design, develop, manufacture, and merchandise their own products; yet these divisions operate within a framework of over-all policy. This framework is the responsibility of 10 top policy-making groups and 3 major decision-making committees. Continuity of ideas is facilitated through an interlocking of membership in these important groups and committees.

Divisionalization is no guarantee of effective control. The recent experience of the Rheem Manufacturing Company illustrates certain limitations attendant upon granting greater autonomy to an organization's components. In 1953 Rheem decentralized on a geographical basis. The managers of the six multiproduct regional units were given a great deal of autonomy but were required to report back to the general manager. Each divisional manager had local control over sales, advertising, manufacturing, and purchasing. Considerable financial independence was given to the managers, who, in turn, were responsible for profitable operations. Regional officials, stressing the profit-center notion, could buy from each other or, if they chose, purchase from competitors. This preoccupation with localized profit and loss statements resulted in a deemphasis of national markets. On occasion the autonomous area heads even ignored unwanted advice from headquarters.

After three years' unfavorable experience with divisionalization, Rheem returned to centralized control. A powerful executive committee was established to supervise the company and its 20 plants.

The de-decentralizing of Blaw-Knox Company is another illustrative case study. More than fifty years of diversification and divisionalization of the corporation's nine divisions had resulted in managers' acting as if they operated nine independent companies. In the 1951 reorganization, divisional autonomy was drastically reduced, with the operating divisions ultimately consolidated into three functional divisions. Centralized control in over-all policy making replaced local control.

From the preceding illustrations, it seems obvious that no single formula for balance in centralized and local industrial control will ever be effected for all industry. Individual differences necessitate variations

in the proportions of headquarters control and local autonomy. Even after an organization discovers a highly satisfactory equilibrium between these two diverse versions of control, it should be realized that this "perfect" balance is only of short-run duration. The dynamism of our economy makes frequent reappraisal absolutely imperative.

SIGNIFICANCE

Control is the very essence of all organization. In the industrial sphere the apex of control, or as it might be more technically termed, the locus of industrial sovereignty, has generally been assumed to be a concomitant of ownership. Sovereignty in this context can be defined as the ultimate power vested in an autonomous group which makes and enforces its own rules for itself and its constituents. This assumption that industrial sovereignty follows from ownership has recently been seriously challenged to the extent that government, labor unions, consumers' representatives, and, more particularly, hired managers have asserted their aspirations to govern industry.

In the initial developmental phases of our present economy, the scarcity of capital gave to the owners of this capital a strategic position. Similarly, in the earlier manorial economy, landowners had acquired the highest privileges. More recently, with the huge aggregates of capital requisite for modern large-scale business endeavor and with progressively higher income and inheritance taxes, it has become practically impossible for an individual to accumulate the necessary capital sums. The increasing supply of funds pooled by millions of small-scale savers and the assumption by government of certain types of financing have likewise served to temper the role of the financier as the strategic factor of production.

The vital importance of managerial ability to our industrial society seems to be an accepted fact. There seems to be universal agreement that this relatively scarce talent has now become the strategic factor in the productive process. Acceptance of this premise implies concurrence in the thesis that the locus of industrial sovereignty has been transferred from ownership to management.

This thesis has widespread ramifications. For example, the profit motive has long been assumed to be the driving force in enterprise. Since today's managers are generally not the corporate owners, the profit motive cannot have the same vitalizing effect. Searching for the basic stimulus which impels the hired managers to action leads to a wide gamut of psychological drives, ranging from crass monetary motives to altruistic and creative impulses. In between these extremes are factors such as the desire for power, the yearning for material

comforts, the striving for security, the need for acceptance, the need for recognition, and the wish to excel. Regardless of the specific motive, it seems evident that economic reward has to a great degree been supplanted by a competition among managers arising from other than monetary desires. This competition is a winnowing device by means of which industry gets better leadership.

Other modifications in this shift in the locus of control have already been mentioned. Nevertheless, attention should probably again be focused upon the increasing importance of integration. Arbitrary action frequently followed from the autocratic control exercised by the typical nineteenth-century captain of industry. Contrariwise, today's captains of industry, the professional managers, have no such dominant position and consequently must rely upon compromise. It must be remembered, however, that in these control-by-compromise situations, there is a powerful centrifugal pull of divergent interests. Sometimes this pull away from the center can be so great as to overcome the centripetal force which theoretically binds all the productive factors into a working organism. Integration by the manager-controller then becomes a complex and very onerous task.

If, as available evidence seems to indicate, a significant metamorphosis is currently taking place in respect to the locus of industrial control, then this subject should receive considerably more attention and careful study since the consequences affect every member of our industrial society.

ILLUSTRATION 1. Ben Fairless on Stock Ownership

A few years ago Benjamin Fairless, then chairman of the board of directors of United States Steel Corporation, made a very interesting public pronouncement. Addressing the Pennsylvania State Chamber of Commerce, Fairless focused attention upon the Marxian premise, namely, that the means of production must belong to the people. Marx maintained that such ownership can be attained only through state control. The means to such control were necessarily violence and revolution. Fairless summarily dispatched this premise by pointing out that "In his thirst for revolution, Marx overlooked completely the only economic system on earth under which it is possible for workers themselves to own, to control and to manage directly the facilities of production. Shocking as the news may be to disciples of Karl Marx, that system is capitalism."

Fairless then proceeded to demonstrate the feasibility of his statement, using his own U.S. Steel as an illustration. According to Fairless's calculations, U.S. Steel's 300,000 employees could, with a very modest

individual investment, buy up all the corporation's outstanding common stock, then numbering about 26,100,000 shares. This would mean that each employee would, on the average, purchase 87 shares at $40 per share; the total average investment would come to approximately $3,500. Even on a modest $10-per-week installment plan, every worker could have paid off his obligation within seven years. The corporation would then be completely owned by the employees.

Fairless even went so far as to suggest an alternative plan, which involved the purchase of only 62 shares of stock per employee. At an average investment of only $5 per week over a ten-year period the corporation's employees would then have voting control of the organization. In Fairless's words, the employees could then "elect their own board of directors, fire the present management, put Phil Murray in my job, and run the business to suit themselves." In a facetious fashion, Fairless concludes, "Clearly, Marx didn't know all the Engels."

QUESTIONS

1. What is your immediate reaction to Fairless's proposal?
2. Do you agree with his computations?
3. Could this transfer of ownership process be accelerated by the investment of union funds, particularly the pension and retirement premiums, in the corporation's stock?
4. Would the proposed worker ownership be conducive to inside or outside control?
5. How would you interpret the increase in the number of Americans owning some stock in publicly held companies from 6,490,000 to 11,000,000 between 1952 and 1959, as estimated by the New York Stock Exchange?

ILLUSTRATION 2. Ownership and Control in the Dennison Manufacturing Company

One of the most staunch advocates of business management as a profession was Henry S. Dennison, president of the Dennison Manufacturing Company from 1917 to 1952. The company, even under his predecessors, had made several major contributions to the field of industrial control by its rather unique plan for placing corporate control and ownership entirely in the management group. The first move in this direction was a profit-sharing plan, instituted in 1878, by means of which the president's "principal helpers" could acquire an interest in the enterprise.

Upon becoming a director of the company in 1909, Henry Dennison reiterated the organization's policy, stressing the importance of keeping voting control within the management group. He even went so far as to advocate the concept that while investors are entitled to a fair dividend and appropriate safeguards for their investments, management is entitled to any earnings remaining after payment of a pre-

determined dividend rate. The logic of this conclusion is based upon the premise that management's efforts create this residual, or surplus, earnings.

The mechanics by which ownership and control have been combined in the Dennison Company's management group for nearly half a century consist in the restricting of voting common-stock ownership to those actively participating in the management of the company. Currently there are approximately 250 stockholders in this category owning about 75,000 shares. When these stockholders retire or die, they or their heirs receive nonvoting common stock in exchange for their shares of voting common stock. This group numbers more than 4,000 individuals. A third category, now termed 8 per cent debenture stock, represents the original common stock which was replaced during the 1911 reorganization. About fifteen years after this innovation Dennison stated:[1]

> Our philosophy of corporate structure holds that only management can truly exercise control but that other parties in interest like employees, investors, and customers as well, perhaps, would have advisory representation with powers of investigation and publicity. If this philosophy proves itself fundamental and gains a wide acceptance, some of the evils most dangerous to the present social order may be on their way to being overcome.

In most respects the Dennison Manufacturing Company's experiment seems to have proved to be successful. Control at all three major levels, ultimate, intermediate, and immediate, continues to be concentrated in the management group. No serious attempt to modify this system of control has been proposed by any of the interested parties. Meanwhile the company has more than doubled sales in the last five years to a present total of more that $42 million. Profit margins approximate 7 per cent on sales. More than 3,600 employees comprise the work force.

While the Dennison experiment has not been emulated, in its entirety, to any appreciable degree, certain recent trends in corporate ownership seem to substantiate the reasoning of this plan's proponents. Practically every major modern enterprise has found it expedient to institute some sort of an executives' stock-option plan. Frequently equity in the company is given to the executive in the form of a bonus. Widespread participation by employees in company-sponsored stock-ownership programs seems to be in keeping with the philosophy of corporate control as enunciated by Dennison. More recently the

[1] Henry S. Dennison, an address at Boston, Mass., The Newcomen Society in North America, New York, 1955, p. 20.

large-scale investment of welfare and retirement funds in corporate stock appears to be a factor favoring the management group as the locus of at least immediate and intermediate control. In the very large enterprise, the magnitude of the investment makes it highly unlikely that the relatively small management group can acquire title to more than a small percentage of the total corporate equity.

QUESTIONS

1. What organizational advantages can you see in this resolution of all three major types of control within one group?
2. What are some of the more serious limitations of this plan?
3. Comment on the statement that management should have priority to residual earnings.
4. Are stock options, stock bonuses, employee stock-purchasing plans, and investment of pension funds in common stock conducive to inside control?
5. Is this example an approximation to codetermination?

ILLUSTRATION 3. Functional Directors and Corporate Performance

The conclusions of a recent study[2] indicate that, for large-scale manufacturing enterprise, inside control is far more conducive to long-run business success than is outside control. The sample of the 200 largest manufacturing companies upon which this survey was based was drawn from *Fortune*'s Directory of the 500 Largest U.S. Corporations. Excellence was judged on eleven factors. Absolute and relative increases in sales, owners' equity, total investment, and profits comprised eight of these factors. Added weight was given to the profit aspect by including the average annual rate of return on owners' equity, the average annual profits, and the average annual operating profit margins. The relative changes were based on performance records for the periods 1922–1928 and 1947–1953. The composition in directorates was compared for the years 1925 and 1950. Changes both absolute and percentagewise in the outside-inside composition during this period are shown in Exhibit 9-2. Although the percentage of inside directors appears to have increased only slightly, from 60.4 to 63.3 per cent, the absolute increase of nearly 200 directors in this category has resulted in a significant shift in the inside-outside directorate balance in certain areas. On the average, each of the 200 corporations added one additional inside director to the average board, which presently numbers approximately 12 members. During this relatively brief period studied and within the sample of 200 large-scale manu-

[2] S. C. Vance, *Functional Directors and Corporate Performance in the Large Industrial Enterprise*, University of Massachusetts, Amherst, Mass., mimeographed, 37 pp., 1955.

Exhibit 9-2. Inside and Outside Directors in the Leading 200 Industrial Corporations, 1925–1950

Category	Number of directors		Percentage of total		Average per board	
	1925	1950	1925	1950	1925	1950
Inside	1,355	1,545	60.4	63.3	6.8	7.7
Outside	884	895	39.6	36.7	4.4	4.5
Total	2,239	2,440	100.0	100.0	11.2	12.2

facturing concerns, the number of companies with 75 per cent or more inside directors increased from 80 to 87. Meanwhile corporations with 50 to 75 per cent inside directors dropped from 44 to 39 and those with less than 50 per cent inside directors decreased from 76 to 74.

A breakdown in the percentage changes by industry groups is shown in Exhibit 9-3. These data indicate that the manager-director is im-

Exhibit 9-3. Percentage of Inside Directors within 16 Industry Groups

Industry group	1925	1950	Change
Apparel and shoe	75	79	+ 4
Tobacco and beverages	71	72	+ 1
Meat packing	66	71	+ 5
Chemicals	68	70	+ 2
Petroleum	70	69	− 1
Auto and transportation equipment	56	68	+12
Paper	63	67	+ 4
Food processing	59	66	+ 7
Rubber	52	65	+13
Miscellaneous consumer goods	66	63	− 3
Building materials and glass	72	60	−12
Nonferrous mining and fabricating	54	58	+ 4
Farm equipment and miscellaneous machinery	59	57	− 2
Steel	52	57	+ 5
Electrical and office equipment	51	54	+ 3
Aircraft	50	51	+ 1
Median	61	65.5	+ 3.5

portant in every one of the 16 industry groups listed. As a note of caution, it should be pointed out that despite this overwhelming evidence, there are still many outside-dominated companies which are run effectively.

When the eleven criteria of excellence in performance were applied and the concerns were ranked by letters *A, B, C, D,* and *E* in decreasing order of excellence, the superiority of inside control became evident. Three distinct tests were used: (1) by industry groups, (2) by groups of ten, stratified as to proportions of inside, intermediate, and outside control, and (3) by groups of 50 comparable-sized companies. The rankings and quality point ratios obtained from these tests are shown in Exhibit 9-4. From this evidence it is obvious that, assuming these

Exhibit 9-4. Rankings and Quality Point Ratios: Five Tests of Corporate Excellence

Test	A	B	C	D	E	QPR
I. By industry groups						
Inside	24	30	22	10	1	2.76
Intermediate	7	10	10	10	2	2.25
Outside	4	11	23	29	7	1.68
II. By stratified samples						
Inside	23	34	20	8	2	2.78
Intermediate	3	9	14	12	1	2.02
Outside	3	6	29	27	9	1.55
III. By samples of 50						
Inside	26	25	23	10	3	2.70
Intermediate	4	12	8	14	1	2.10
Outside	5	11	19	25	14	1.57
IV. American Institute of Management						
Inside	6	11	15	18	37	2.42
Intermediate	—	9	9	4	17	2.50
Outside	2	11	5	14	42	1.76
V. *Forbes Magazine*						
Inside	7	8	6	3	—	2.79
Intermediate	3	1	2	—	—	3.16
Outside	3	2	3	6	—	2.14

tests are valid and reliable, inside control tends to yield superior long-run results in the large-scale manufacturing enterprise.

This superiority is further emphasized when the outstanding concerns are selected from the sample of 200. Of the 20 top-ranking companies shown in Exhibit 9-5, 17 are inside-controlled corporations and 3 are of the intermediate classification. Of the top 50 companies, 35 are of the inside category (those with more than 75 per cent professional manager-directors). In the intermediate group (50 to 75 per cent inside directors) there are 8, and in the outside group (less than 50 per cent inside directors) there are 7. Despite the comparable number of inside and outside companies in the sample studied, ap-

Exhibit 9-5. The 20 Outstanding Large Industrial Corporations

Corporation	Category	Tests		
		I	II	III
E. I. du Pont de Nemours	Inside	A	A	A
General Motors	Inside	A	A	A
Standard Oil (N.J.)	Inside	A	A	A
Philco	Inside	A	A	A
Minnesota Min. & Mfg.	Inside	A	B	A
Borg-Warner	Inside	A	A	A
Archer-Daniels-Midland	Inside	A	A	A
Jos. E. Seagram & Sons	Inside	A	A	A
Monsanto Chemical	Inside	A	A	B
Procter and Gamble	Inside	A	B	A
General Foods	Intermediate	B	B	A
Celanese	Inside	A	A	A
Thompson Products	Intermediate	A	B	A
Deere	Inside	A	A	B
National Dairy Products	Intermediate	B	C	A
Kaiser Steel	Inside	A	A	B
Rockwell Spring & Axle	Inside	B	A	A
Caterpillar Tractor	Inside	B	A	A
Minneapolis Honeywell Reg.	Inside	B	B	A
Owens-Illinois Glass	Inside	A	B	B

proximately five or six times as many inside concerns rated *A* rank as compared with the outside companies.

QUESTIONS

1. Do you think the conclusions derived from this study would be equally valid for industries such as railroads, banking, insurance, merchandising, and public utilities?
2. Would it be logical to conclude that 100 per cent inside control is the ideal for industrial management?
3. What appear to be the chief limitations (*a*) of inside control, (*b*) of outside control?
4. Is inside control comparable with codetermination?
5. What modifications in the premises and techniques of this study might be expected to yield somewhat different conclusions?

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CHAPTER 10

Measures of Performance

DEFINITION AND DESCRIPTION

Effectiveness in performance is always measured in terms of some specific objective. Attainment of the objective signifies successful performance. An approximation to the objective signifies an incomplete mission or failure, the extent to which the objective was approximated being equal to the measure of success in that specific performance.

One of the strongest objections to the application of quantitative techniques to the measurement of administrative actions is the supposed difficulty in equating human endeavor in tangible terms. However, as was stressed in Chapters 4 and 8, cause-effect relationships, attributes, and even performance can, with certain limitations, be expressed quantitatively and to that extent at least can be measured. It must be conceded that quantification of supposedly nondimensional items frequently necessitates the use of judgment and ingenuity. Common sense dictates that a rational being periodically evaluates his activities in terms of the question: Are they, or are they not, in accord with predetermined objectives? Assuming that they are in accord with objectives, a further evaluation as to how closely they approximate attainment of the objective generally follows. This simple mental process is expressed in Exhibit 10-1, where the line *OG* represents the gamut of stages from *O*, the *origin* of the action, all the way to *G*, the immediate *goal*. Any single *point* (*P*) along this line would

represent the culmination of performance (OP) up to that point in time. If OP coincides with OG ($OP = OG$), then performance is completely effective since the goal has been reached. If OP is less than OG ($OP < OG$), then the objective has not been reached and performance is only partially successful. It is even possible for OP to be greater than OG ($OP > OG$), when the stated objective has been exceeded.

Designating *effectiveness* E in terms of *performance* OP and *objective* OG, a simple ratio, $E = OP/OG$, measures success in accomplishment. When circumstance permits precise measurement on the basis of adequate data, the line OG can be graduated so that each point along this line of objective has a specific value. In this instance it is relatively simple to translate OP into absolute and relative terms. Thus line OP in Exhibit 10-1 might represent the completion of 1,500 units out of a scheduled order of 5,000 units. In relative terms this would mean that 30 per cent of the objective has been realized.

On the other hand, if exact point calibration is impossible, then a simple "range-type" sequence such as shown in Exhibit 10-1 can be

Exhibit 10-1

O	P	G
0	v	1

Failure—Poor—Average—Good—Excellent

used, with a descriptive word or phrase indicating the measure of success. It is obvious that even this second technique for evaluation can, with facility, be converted into numerical values by a variety of methods, assuming an arithmetic or even a geometric progression from point O to point G. This rather elementary explanation for an almost universally accepted evaluation technique has been ventured to emphasize that much of what is considered to be subjective, intangible, and even metaphysical can be measured, compared, and judged. Contentions that the actions and especially the thoughts of human beings defy measurement are frequently flimsy pretexts for evading an evaluation process which can be onerous, perplexing, and weighted with responsibility.

In the preceding chapters reference was made to a number of terms closely associated with measurement of company-wide, or industry-wide, performance. The following is a recapitulation of the more important of these terms:

1. Profit. This has been defined as the differential between the costs of production and value received for goods produced and services

rendered. Because of its paramount importance to industrial administration, the concept of profit will be given specific attention in corollaries 1 and 3.

2. *Productivity.* This is the rate of output in terms of a specific unit of input. Productivity is generally expressed as a ratio of the average performance in terms of an average man-hour of labor expended in the process. Some further considerations of productivity are presented in corollary 2.

3. *Production Equation.* Although this norm is not commonly used, it is important because it represents total output as a function of the combined efforts of all the pertinent factors of production. Precise measurement by means of the production equation would indicate changes in over-all productivity and in the productivity of the several components. This would facilitate the selection of optimum production combinations and the equitable apportionment of the gross product. Reference has already been made to the use of the production equation in Chapter 1 (pp. 21–22) and in corollary 3, Chapter 8.

4. *Value Added.* Creation of utility, which is the prime objective of all industrial activity, is measured through value added. As was explained in the section on definition and description in Chapter 3, value added is equivalent to the contributions of manpower and machine power by means of which the usefulness of goods and services is enhanced. In computing value added it is important to avoid "double-counting," which results when the cost of purchased goods and services is not subtracted from the gross value of output. Purchased goods and services represent value added by other agencies and hence should not be attributed to the enterprise which uses that good or service as a raw material or a base upon which to create additional utilities.

5. *Power Factor.* This concept refers to the ratio of usable potential in terms of latent potential. Effectiveness of organization is measured by the extent to which this ratio approximates unity. As stated in Chapter 6, this concept is fundamental to the comprehension of the maximum use of resources.

In addition to these rather generic measures of performance, every functional area has specific criteria for evaluating functional activities in terms of specific objectives. Space limitations and expediency make impossible a more detailed digression. Many of these measures will be explained in the appropriate technical chapters in Part Two. At this point, a summary listing of some of the more important criteria of performance should suffice.

1. *Over-all Effectiveness of Individual Plant (Ferguson's Formula)*

$$E = aK + bT + cU$$

where a = per cent effectiveness of organization
b = per cent effectiveness of technical facilities
c = per cent utilization of all facilities
K = factor of organization for a particular industry
T = technical-facilities factor
U = utilization of knowledge and facilities factor

$$K + T + U = 100$$

2. *Span of Control (Graicunas's Formula)*

$$F = A + B + G$$

where N = number of subordinates
A = number of direct single relationships
$A = N$
B = number of cross relationships
$B = \frac{N}{2}(N - 1)$
C = number of direct group relationships $= 2^N - (N + 1)$

3. *Laborsaving Ratio*

$$S = 1 - \left(\frac{W}{F} \times \frac{1}{P}\right)$$

where W = number of workers required by new method
F = number of workers required by old method
P = ratio of total outputs, new method to old method

4. *Economic Lot Size*

$$Q = \sqrt{\frac{2YP}{UC}}$$

where Y = annual requirement of a specific product
P = average order, machine, etc., preparation costs per order
U = average unit costs
C = average carrying charges expressed as a decimal

This basic equation can readily be modified into many complex forms by the injection of other variables such as space factor, in-process inventory, inventory build-up, quantity discounts, etc.

5. Equipment Replacement Equations (Terborgh's Formulas)

(*a*)

General, no-salvage-value formula for challenger's adverse minimum

$$= \sqrt{2cg} + \frac{ic - g}{2}$$

where g = annual inferiority gradient, dollars
n = years of service
c = acquisition cost
i = interest rate, as a decimal
s = salvage value at end of period n

(*b*)

General formula for defender's adverse minimum

$$= \text{next year's inferiority} + \frac{g(n-1)}{2} + \frac{c-s}{n} + \frac{i(c+s)}{2}$$

These formulas will be discussed in this chapter under the equipment-replacement policy.

6. Gantt Charts. These are graphic presentations emphasizing the importance of time in respect to work planned and work done. Among the best known of the Gantt charts are progress charts, man-machine record charts, layout charts, and load charts. The basic principles of Gantt charting and several illustrations will be presented in subsequent chapters.

7. Break-even Charts. These are graphic illustrations of the relationship between sales volume, costs, and profits. Such relationship can also be expressed in descriptive form, in a tabular presentation, or by equation. For example, $X = Fc + (Vc/S)X$, with X, Fc, Vc, and S representing the break-even point, fixed costs, variable costs, and sales, respectively. While this expression of sales-cost-profits relationship by equation might be of value, graphic presentation is by far more succinct. The technique of break-even analysis and its uses will be discussed in Chapter 15.

There are in addition numerous equations, ratios, formulas, charts, curves, diagrams, nomographs, tables, and other devices useful in measuring specific industrial activities. In every instance these measures employ some accepted standard and equate expectancy and performance in terms of that standard. A comprehension of these and related measuring devices is becoming more and more mandatory for high-level technical competency in the art and science of industrial management.

DEVELOPMENT

The use of standards and measuring devices in the sphere of industrial activity is a logical result of the metamorphosis from hit-and-

miss management, through systematic management, and thence into scientific management. It is virtually impossible to describe in detail the development of each of the industrial performance measuring devices currently in use. The many techniques have originated in as many different sources. Probably the most important single source of these techniques, in the technical sphere of production, was that venturesome group of pioneers closely associated with Frederick W. Taylor. It was this group that hastened the transformation of industrial management from an avocation to a vocation, with all the attributes of a profession, including its own distinctive philosophy. In their enthusiastic advocacy of scientific methods for industry, the Taylorites spawned numerous ideas as to how industrial activity could be evaluated in terms of contribution and objective.

It would be repetitious to describe the sequence of events and the gradual change in thinking which accompanied the introduction of scientific performance-measuring techniques in industry. Although most of these norms are currently accepted in scholastic circles and by forward-thinking and technically competent industrial managers, the use of relatively few of these performance yardsticks has as yet become universal. Admittedly, some of the more complex measures have very limited use. For example, despite their mathematical accuracy, very few of the recently introduced operations-research techniques have had more than an experimental application in industry. The factors responsible for this slow response have already been mentioned.

While there apparently is justification for caution in the adoption of costly and complex performance-measuring methods, many segments of industry have been unnecessarily remiss in using proven and cost-justifiable methods. The skepticism manifest in respect to a more intensive-extensive adoption probably follows from:

1. The established tradition of rule-of-thumb evaluation.
2. The relative technical difficulty of even the less complex measures.
3. The difficulty in defining factors, terms, causes and effects.
4. The "practical-man" fallacy which overemphasizes the function of experience in the acquisition of judgment-making ability.
5. The negative experience associated with certain management fads. The reaction to "efficiency expertism" as practiced by many quasi consultants in the post–World War I era is a good example.

Probably the most universally accepted norms of industrial performance are those pertaining to financial statements. One reason for such widespread acceptance is the rigid regulation imposed upon profit-making concerns by tax-collecting agencies. Expediency in respect to tax laws has fostered some semblance of uniformity in the definition

of such terms as *net income*. Yet even in this most stringently regulated sphere there is considerable difference in opinion as to definition and method of computation.

The most important single reason for the slow adoption of the more meaningful industrial performance measuring techniques was the lack, up to rather recently, of what could legitimately be called a profession of industrial management. One of the hallmarks of a profession is the availability of demonstrated performance measures accepted by the professional body, its clients, the government, and the public. Until industrial managers can inject more "science" into methods of evaluation, and until universal adoption of these techniques is more nearly reached, there will continue to be some doubts about the stature of the fledgling management profession.

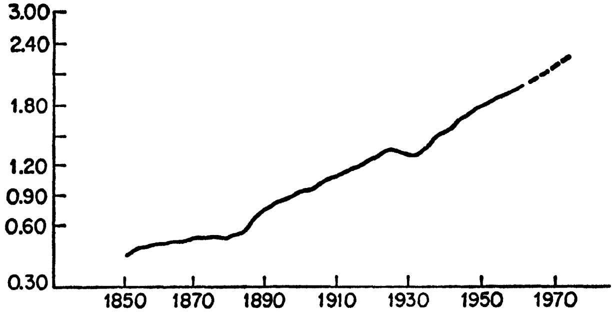
COROLLARY 1. Productivity

One of the most important concomitants of scientific management has been a sustained and remarkably high upward progression in productivity, that is, in the rate of output per unit of input. Productivity, usually measured as the quotient of total output divided by the total man-hours employed, is the best single index of industrial efficiency. Although productivity is generally associated with manpower units, it can be used to measure the rate of output in terms of any factor of production. In a sense, then, we can speak of the effectiveness in use of the invested dollar, machine-hours, and any other input item. However, caution should be exercised not to attribute gains in productivity exclusively to any single factor. Thus a rise in productivity, as measured in output per man-hour, might be due almost entirely to the introduction of improved machinery or better methods.

Another limitation in the better understanding of the concept of productivity is the oversimplification in the reduction of the factors of production into land, labor, and capital. Closer study of these broad categories, together with the government and management factors, discloses a great many variables which affect the rate of output. For example, the labor factor should be viewed not only in terms of quantity but also in respect to degree of skill, general education, health, degree of unionization, geographic mobility, attitude toward change, reaction to length of hours of work and to method of compensation, and above all, the status of that ephemeral quality generally called morale. Many other variables affect the labor factor and the other components of the industrial process.

A numerical figure expressing the rate of output for a specific year or plant or company assumes meaning when it is compared with

Exhibit 10-2. U.S. Gross Product (Private) per Man-hour in 1953 Dollars (Logarithmic plot for rate of growth)

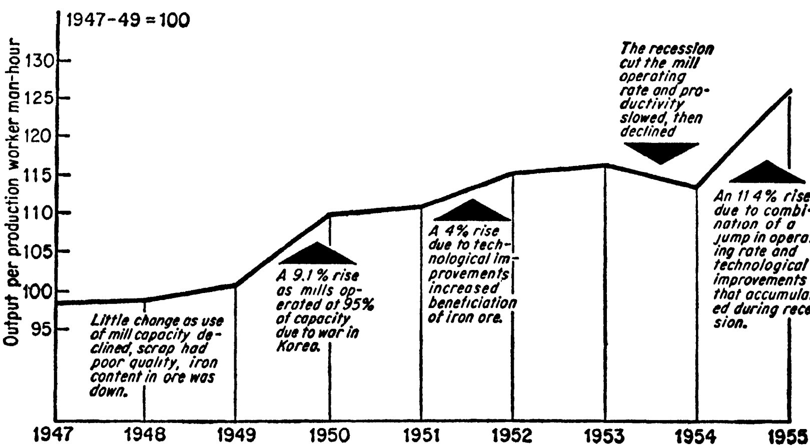


SOURCE: Gilbert Burck, "The Engine: Rising Productivity," *Fortune,* January, 1955, p. 71.

similar numerical terms for other years, plants, or companies. Thus Exhibit 10-2, using a time basis, clearly indicates that the past century has witnessed a remarkable upsurge in productivity. After making adjustments for the effect of compounding increases, it is conservatively estimated that the average annual rate of increase over the past hundred years has been approximately 2 per cent.

The Bureau of Labor Statistics, in its 1956 study of the steel industry, demonstrated very graphically that there are sharp year-to-year variations in productivity. This is evident from Exhibit 10-3, where, for

Exhibit 10-3. The Erratic Behavior of Steel Productivity



SOURCE: *Business Week,* Oct. 13, 1956, p. 53.

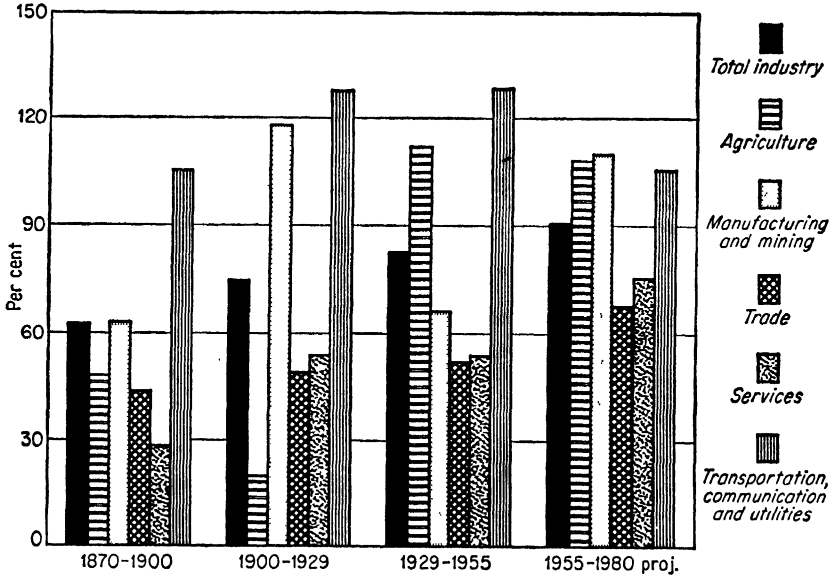
example, a decline in 1954 was followed by a sharp rise in 1955. The Bureau concludes from this study that the single most important factor in the year-to-year fluctuations is the extent to which productive capacity can be utilized. Thus the sharp 9.1 per cent rise for 1950 is attributed in large measure to the 95 per cent steel-capacity utilization during the Korean War. The 11.4 per cent rise in 1955 was likewise closely related to full use of facilities. The spectacular increases are also closely linked to technological improvements such as the increased beneficiation of iron ore, increased size of blast furnaces, the increased number of electric furnaces, and many other innovations. Over the 8-year period shown in Exhibit 10-3, the annual gain for the entire steel industry averages about 2.9 per cent. Other substantial increases in the steel industry include gains of 18 per cent in 1939, 12.9 per cent in 1928, 13.6 per cent in 1925, 27.6 per cent in 1922, and 27.3 per cent in 1920. In the 32-year period covered by the Bureau of Labor Statistics study, there were also 8 years with losses in productivity. Thus it is obvious that the upward progression of productivity is not an evenly paced climb but rather an unpredictable series of leaps and slumps.

Despite periodic fluctuations, the trend in productivity has been progressively upward. Between 1850 and 1870 the rate was less than 1.5 per cent. It rose to 1.6 per cent between 1879 and 1920 and to 2.5 per cent from 1920 to 1947. Since then the rate of productivity has averaged around 2.9 per cent. Estimates as to future performance generally are rather optimistic. *Fortune* predicted that the increase from 1955 to 1980 will average slightly less than 3 per cent. In 1955 the Subcommittee on Economic Stabilization, Joint Congressional Committee on the Economic Report, estimated that the increase will be approximately 2.8 per cent between 1953 and 1965. These changes have not been and will not be uniform in all industries, as is shown in Exhibit 10-4. It should be emphasized that the utilities, communications, and transportation industries, which according to the chart have grown more efficient faster and more steadily than other industries, have several distinct advantages. They cater to a rapidly expanding market and provide relatively changeless products, usually in a continuous operation. *Fortune's* 1955 estimate as to near-future productivity changes indicates that an annual 3 per cent gain will result in a doubling of production per man-hour in less than 24 years, a quadrupling in 47 years, and an eightfold multiplication within 71 years.

The remarkable aspect of this gain in the rate of increase is the realization that the effect of diminishing returns in production has, at

least temporarily, been forestalled. This phenomenon has been achieved despite the pessimistic preachments of Lord Keynes and his cohorts. These underconfident economists had postulated that ours was a mature economy. In a mature economy it is assumed that there will be few, if any, major inventions, and even refinements upon the older inventions can only be made at disproportionately high costs. Thus

Exhibit 10-4. Productivity Growth in Four Eras



SOURCE: "Productivity: The Great Age of 3%," *Fortune,* November, 1955, p. 104.

the mature economy gradually sinks into the placidity of *status quo.* The fallacy of Keynesian assumptions has been clearly proved during the past two decades. It might be said that their mistake was due to an underestimation of modern management's potential and of the inventive ability of American technicians. Despite dire Keynesian predictions, the trend of productivity continues upward at even a faster pace than ever before.

The meaning of productivity is aptly summarized in the impressions of foreign observers. In the past 10 years, first under the auspices of the Marshall Plan's Anglo-American Council on Productivity and later under the Foreign Operations Administration, almost 20,000 foreign managers, technicians, and labor leaders were brought to the United States. After visiting nearly 5,000 American factories, universities,

laboratories, and other establishments, they had varying impressions of our system. *Fortune,* quoting several comments, presumably typical, states:[1]

"American operatives do not work harder than their opposite numbers in Britain, nor are their machines in general better tooled or superior, though there is clearly more mechanization. Their high productive efficiency is due largely to more accurate planning by management and more constant analysis of methods."—The British industrial-engineering team.

"[In the U.S.] productivity is a state of mind. It is the mentality of progress, of constantly improving what there is. It is the willingness not to be content with the present situation, however good it may be. It is the continuous effort to supply new techniques and new methods. It is faith in human progress."—The French Association for the Improvement of Productivity.

The tangible results testifying to the superiority of the American concept of productivity are expressed in the following record of the past century:

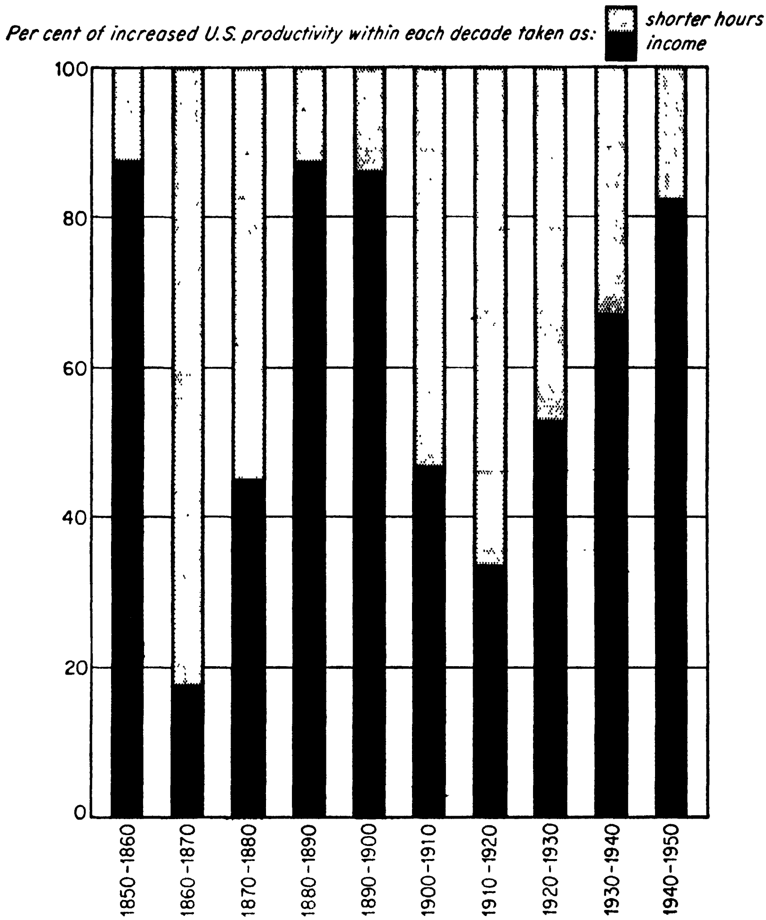
1. The number of privately employed workers increased from about 7 million to nearly 66 million.
2. Man-hours worked rose from about 26 billion to about 140 billion.
3. National gross product, exclusive of government services and expressed in current dollars, increased from about $15 billion to more than $450 billion.
4. National productivity, expressed as gross national product per man-hour in current dollars, rose from about 45 cents to more than $3.
5. Per capita real income has been multiplied about five times.

This fivefold rise in real income has been achieved without any fantastic speed-up or greater outlay of human effort. On the contrary, there have been significant reductions, totaling more than 40 per cent during the past century, in the length of the work week, allowing the workers more leisure time for the enjoyment of the greatly increased quantity of products. Disposable income per family, measured in 1955 dollars, will rise, according to *Fortune,* from $4,400 to $8,000 in the quarter century ending in 1980. Concurrently, the average work week will decline from 41 to about 35 hours. Exhibit 10-5 shows how, since 1850, the increased productivity has been allocated between higher incomes and shorter working hours.

The net result of American production methods is a concentration of more than 50 per cent of the world's factory-produced goods and 40 per cent of total world output in this country, to be shared by less than 6 per cent of the world's population. It is interesting to

[1] Gilbert Burck, "The Engine: Rising Productivity," *Fortune,* January, 1955, p. 68.

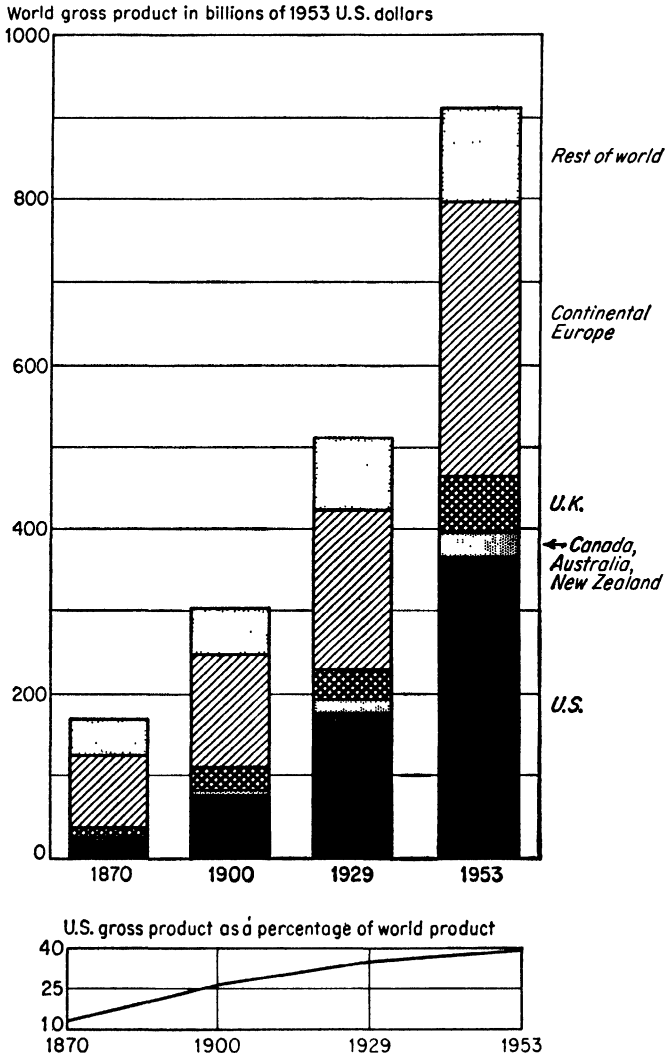
Exhibit 10-5. Distribution of Productivity Gains between Income and Shorter Hours



SOURCE: Gilbert Burck, "The Engine: Rising Productivity," *Fortune*, January, 1955, p. 71.

note from Exhibit 10-6 that in 1870 the gross output of continental Europe was 4 times as great as that of the United States, but today is nearly 10 per cent less. The United States has raised its share of the total world output from 13 to 40 per cent, thus increasing output by more than 16 times in the past 90 years. During that interval the United Kingdom has increased output 5½ times; continental Europe less than 4 times; and the rest of the world 2 times. Although an

Exhibit 10-6. Distribution of World Gross Product



SOURCE: Gilbert Burck, "The Engine: Rising Productivity," *Fortune*, January, 1955, p. 70.

abundance of natural resources and a homogeneous and mass market are frequently emphasized as being key factors in this dynamism, it should be pointed out that other areas of the world have equally good resources and vast market potentials. Mass markets and rich

natural resources should not be discounted as being conducive to economic progress, but the most impelling forces are probably (1) an indefatigable optimism, (2) resourcefulness and inventiveness, (3) willingness to forgo present spending in order to accumulate capital, (4) a dynamic technology, and (5) managerial talent to organize and direct work effectively.

Productivity has been termed "a state of mind." As such, it is an inseparable adjunct of the philosophy and practice of scientific management. It is also the best single indication of a sound economic mind, in a well-organized economic structure, creating goods and services at the highest possible rate and to the greatest possible satisfaction of all participants.

COROLLARY 2. Profit

Profit has already been defined as the differential between costs of production and selling price. This differential varies in proportion to the ability of the entrepreneur to maximize selling prices and to minimize input costs. In this capacity the entrepreneur tends to be more or less successful according to the extent to which he assumes exceptional risks, applies special diligence and effort, or contributes desirable innovations. Riskless endeavor, while it might provide for adequate compensation of the basic productive agents, seldom yields a residue or differential for entrepreneurial abilities.

In a sense, all profit in a free-enterprise system is monopolistic in so far as it represents payment for a scarce and difficult-to-duplicate attribute, good, or service. In this context profit is an inducement for relinquishing possession of desired and scarce utilities. This monopoly in the sphere of music might be the compositional genius of a Wolfgang Amadeus Mozart, the directive brilliance of an Arturo Toscanini, or the vocal talent of an Ezio Pinza. The possessor of such a musical monopoly can demand a premium only as long as there is a scarcity of this service, together with individuals who are willing to pay the premium prices for the satisfaction afforded by these services.

In the field of industry, a patent provides a monopolistic return, properly called profit, to the inventor. Once the patent protection is removed, profits tend to diminish rapidly and selling prices tend to approximate costs of production. This follows because removal of entrance barriers and the prevalence of high-profit expectations will usually attract many individuals willing to provide the specific goods and services. Ultimately, increased productive capacity leads to increased supply and to a satiation of demand. A lessening of want

intensity leads to a dwindling in premium prices and to decreased profits.

It must not be inferred from this supply-demand analysis that profits are only maximized when supply is restricted in an absolute sense or when the profit differential is at its maximum. Actually, it is not absolute scarcity, but rather relative scarcity, which affects profit maximization. For example, profits will not be maximized if a particular product or service is so priced that only the very highest income groups can afford its purchase. On the other hand, reducing the price and catering to the significantly more numerous lower-income individuals will tend to result in increasing the absolute supply of the item. However, since there are now many more who seek the product or service, relative supply can actually be lower. Advertising, by informing more people of the existence and merits of products and services, is the greatest single force in effecting this change.

Similarly, volume is important in maximizing profits. Despite a low unit profit rate, total profits can be maximized by significantly increased volume. This is particularly the case where mass markets exist and where the product or service is a consumer item used frequently.

Referring to illustration 1, it becomes apparent that even if the basic definition, profits equal selling price minus cost of sales, is accepted, there is still ample opportunity to disagree as to the meaning of the term. There is a distinct difference between profit in a planned economy and profit in a free-enterprise system. The former is a fiction; the latter is a lubricant facilitating the effective functioning of the free-enterprise mechanism. The single most important differentiating feature is the fact that free-enterprise profit is a reward for superior contribution following the expenditure of extra effort or ability, the assumption of special risks, or the discovery of better products, better mechanisms, or more efficient technology.

Even in our own system there are several aspects of profits which sometimes lead to confusion. The most perplexing of these is the distinction between profits before taxes and profits after taxes. Technically, if taxes are considered as a legitimate cost of doing business, and if taxing agencies are viewed as factors of production providing useful services, then such charges should be deducted before the residue can properly be labeled a profit. It is ludicrous to lump into an aggregate funds which belong to two such distinct agents of production as government and the entrepreneur. Although some semblance of differentiation is found in the terms *gross profit* and *net income,* it would seem equally logical to talk of gross profit before payment of wages, depreciation, etc.

Another aspect of profit, termed net operating profit, serves to distinguish the income-cost differential in reference to the prime business activity in which the concern is engaged. Thus, for a manufacturing enterprise, net operating profit would not include income from such extraneous sources as interest on deposits, dividends, and royalties, profit on sales of facilities or investments, etc. Net operating profit also views the residue prior to tax payments.

Net earnings or net profits can also be differentiated as before or after dividends on preferred stock. Actually, since such payments are of a contractual nature and must be deducted from the sum remaining for distribution among the equity owners, net profit before provision for preferred dividends is not "pure" profit.

There are many other angles of appraisal pertinent to a better comprehension of the profit concept. Our interest, however, is limited at this point to a consideration of profit as a measure of industrial performance. It would be trite to develop the theme that profit is the best gauge of business success. Such an assumption is accepted by all but the poorer-informed members of our society. An industrial manager, however, must proceed from such an assumption to the requisite implementation by means of which long-run profit is maximized and stabilized. Acceptance of this premise and diligent application of adequate means for its attainment is the surest way to effective organization.

COROLLARY 3. Lineal Extension of Profit

There has been considerable debate as to the priority of purpose in industry. A half century ago there was practically unanimous sentiment, in and out of industrial-management circles, that profit was the guiding principle in all areas of business endeavor. More recently this concept has been challenged by proponents of the service concept which stresses that industrial organizations have obligations to customers, employees, and the public in general which supersede profit considerations. While this section will not weigh the arguments for or against these supposedly divergent views, an attempt will be made to redefine profit motivation in terms of (1) long-term profit prospects and (2) the significance of service to long-term profit maximization.

The lineal extension of profit concept is, in effect, a proposal to stabilize profits, not by government edict but by long-range corporate planning. The goal consists in determining the optimum rate of return on investment or sales which the company should strive to attain over a long period of time. This concept, which might also be labeled profit planning and control, is at variance with the very prevalent notion that

maximum profits should be reaped immediately as circumstances permit since there is no foretelling the future. The gyrations in profit pattern typical of most corporate performances reflect this prevailing philosophy. The lineal-extension-of-profits concept, on the other hand, proposes a leveling so that excessive skyrocketing and depressive plunging of profits would be smoothed into a more stable profit pattern.

Among the more important components of this profit-planning concept are (1) the setting of a specific profit objective consistent with sound continuous growth and competitive conditions, (2) a projection of this objective into the corporate components down to the departmental level, (3) a rigid application of profit standards to actual performance, (4) a coordination of all the organization's units into a unified and controlled course of profit aspiration, and (5) a modification of procedures, plans, and objectives as expediency dictates.

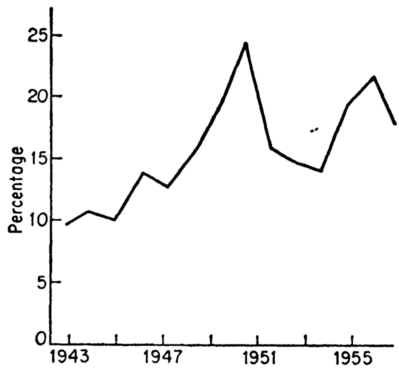
The first significant attempt at profit cultivation was ventured in 1919 by E. I. du Pont de Nemours Corporation upon its shift of emphasis from munitions to chemicals. An over-all objective, a rate of return of approximately 10 per cent on investment, was established. Then the organization was decentralized, and each component was ascribed a specific profit objective consistent with the over-all 10 per cent rate of return. A system of graphic presentation of data was instituted for control purposes. Currently, about 350 different charts are used in the du Pont company for profit-control purposes. The concept of a carefully nurtured profit rate logically spread to the General Motors Corporation when Donaldson Brown, deviser of the du Pont profit-planning system and treasurer at du Pont, became financial vice-president of General Motors in 1921. Subsequently, practically every major industrial organization adopted at least some of the major features of the concept of planned and controlled profits.

The concepts of budgets, forecasts, and especially of profit centers are intimately associated with the lineal-extension-of-profits idea. Actually, the basic notion of planned and stabilized profits depends upon sound cost-accounting principles, optimum utilization of productive facilities, accurate estimating of product demand, and adequate financial analysis.

Setting a predetermined optimum long-run rate of return on investment or on sales is equivalent to profit planting, entailing the sequence of preparing the soil, sowing, fertilizing, irrigating, etc. This analogy with agriculture also brings to mind that in business as in farming there are certain uncontrollable elemental forces. Consequently, planning in either sphere is necessarily subject to interference from the unknown.

Control of pertinent factors and prediction of probable outcomes, which are basic to lineal extension of profits, hinge on mathematical techniques. A fundamental step in the application of the concept is an analysis of past performance. While a projection of the performance curve would be somewhat helpful, it is vital that all pertinent factors be studied to note tendencies of a shift in this curve. Exhibit 10-7

Exhibit 10-7. Ratio Net Income to Net Worth, I. E. du Pont de Nemours Corporation, 1943–1956



shows graphically the profit-investment relationship at the du Pont company for the period 1943 to 1956. This condensation of the data into graphic form facilitates fitting the pertinent figures to a curvilinear relationship. The curve, incidentally, can be hand-fitted or determined by the well-known least-squares method, using the equation $Y = mx + b$. Curve fitting by statistical means, while it requires a measure of technical competency, yields results which generally are more accurate than those associated with curves drawn by the hand-fitting method.

Analyzing the graph, it is obvious by inspection that the profit-investment relationship, except for the first three years, is considerably above the 10 per cent objective previously mentioned. Actually, there seems to be a noticeable upward trend in the ratio of net income to net worth. Analyzed in retrospect, it is evident that socio-economic-political forces, such as those which emanated from the recent wars and the postwar adjustments, affected the critical variables of production and especially:

1. Rates-of-capacity utilization
2. Competitive pressures in distribution and consumer preferences
3. Taxation policies

4. Pricing policies
5. Labor attitudes and wage policies

A rather obvious inference can be injected at this point. Unless the profit planners can anticipate all significant variances within the important parameters, the lineal-extension-of-profit concept becomes unrealistic and unworkable. Anticipating change is one of the prime functions of scientific management. In order to anticipate, to predict, and finally to control organizational activity, it is of paramount importance that adequate means be available for measurement of performance. The more explicit these means and the more the pertinent data can be expressed in equation, formula, tabular, or graphic form, the greater will be the facility with which industrial performance will be properly evaluated, planned, and controlled.

COROLLARY 4. Some Financial Norms

In addition to productivity and profit, the best-known general criteria of industrial performance are those related to financial analysis. Among these measures are earning power, market value of common stock, book value of common stock, growth in sales, growth in equity, growth in capacity, and a great variety of financial ratios such as the current ratio, the "quick" ratio, ratio of net earnings to tangible net worth, inventory turnover, etc.

Earning Power. This is actually one aspect of the profit concept. The ability of a concern to utilize its facilities effectively so that there is a yield, or return, on investment constitutes the basic function of industry. Earning power pertains to the potential inherent within a given company to attain and maintain a certain rate of return. This earning ability is of paramount importance because it is the best single barometer of organizational effectiveness. A relatively high earning power invariably means a sound organization structure, a dynamic staff, technological superiority, and competitive alertness. A low earning power, while it is frequently blamed on extraneous factors, such as over-all industry doldrums, is usually symptomatic of sluggish management.

Market Value of Common Stock. In a corporation, ownership is manifest through shares of common stock representing title to a portion of the corporate equity. The stated market price of these shares indicates that, in the opinion of individuals who are willing and able to pay the stated price, these shares have a given value. The actual market price affixed to a specific share of common stock is determined by a complex and composite evaluation resulting from the sentiments and judgments of all interested parties. Among the more important

price-determining forces is the degree of confidence engendered by the concern whose stock is being priced. An expectation of a high earning power, together with other similarly favorable factors, leads to premium prices. Generally, the base for setting market-value calculations is book value, or better still, liquidation or salvage value. This rock-bottom price is increased, and sometimes decreased, in proportion to earning prospects. Unfortunately, this liquidation value plus capitalized earning power basis for determining market value is too frequently affected by factors such as rumor, emotion, a crisis mentality, and fantastic expectation. Nevertheless, market value of common stock serves as one of the surest measures of corporate effectiveness in its functions of creating utility and maximizing profits.

Book Value of Common Stock. This norm shows a quasi-fictional worth of the equity holder's investment. It is derived by subtracting all claims against the company from the sum of the assets. The residue, or net worth, is then divided by the number of shares outstanding to determine the proportional value per share. In a sense, this measurement is purely hypothetical since many intangible items, such as good will, are excluded. Yet these intangibles are frequently among the organization's most important assets. The fundamental concept of trading on the equity which is basic to all borrowing for investment purposes rests heavily on intangible good will. Then too, the value of a share of common stock in a going concern is invariably much higher than the value of the same share if that company were being liquidated. Generally, a rise in book value, after price-level adjustments, is associated with successful performance and sound management. Finally, in considering either market or book value, it is important to note that changes in the number of common-stock shares outstanding affect computations.

Criteria of Growth. Expansion in scale of operation is invariably assumed to be a by-product of effective industrial management. This is particularly true in a rapidly developing economy where some of the growth norms, such as dollar volume of sales, are affected by population changes and price-level fluctuations. Consequently, in a dynamic situation, much of the growth is simply a pace-keeping adjustment. A better standard would measure relative growth, in terms of competitors, the industry, or the economy as a whole.

Growth in sales, in equity, and in capacity is the best known of these positive indications of progress. While it is admitted that an individual enterprise very seldom has any significant long-run control over consumer habits, nevertheless it is presumed that an agile management will adjust its product mix according to prevailing demands.

Thus the manufacturer of snuff could hardly blame the decline in snuff consumption for a comparable slump in the company's performance. There are few barriers preventing a forward-thinking management from shifting emphasis to related products or even into a diversified field. Relative growth in sales, then, is a good measure of over-all excellence in performance.

An increase in equity, once again adjusted for price-level changes, is also a fairly good index of sound and effective management. Poor performance, in the long run, could scarcely inspire investors to put additional funds into a questionable venture.

Growth in capacity is a much more difficult criterion to use because of the complexities entailed in computing capacity. Size of labor force, man-hours utilized, investment in equipment, and similar terms have serious limitations as measures of productive capacity. A shift from a manual operation to a mechanized process is extremely difficult to equate in terms of manpower and machine power. There is no single gauge which will convert adequately, into homogeneous units, the various items which constitute an industrial organization's total productive capacity. Yet in theory the capacity criterion would probably be among the best measures, since actual performance could be judged in terms of potential.

Financial Ratios. This category includes the best-known measures of business performance. The *current ratio,* obtained by dividing current assets by current liabilities, indicates the relative liquidity of the enterprise. This liquidity, with a ratio of 2:1, long assumed to be standard for industry in general, measures the ability of the company to meet its immediate obligations. A low current ratio is a warning that the concern can easily drift into financial embarrassment.

Another useful norm is the *quick ratio,* sometimes referred to as the acid test. This ratio is computed by dividing current liabilities into the sum of liquid assets, namely, cash and readily cash-convertible receivables and securities. The logic underlying the use of this rather rigid test is the knowledge that payment of current claims can be made only from the more liquid assets.

Inventory-turnover ratios are frequently indicative of effective management. The rapidity with which specific items are moved affects a variety of costs and particularly those associated with the use of working capital. This ratio should be used with great caution since there is no single yardstick applicable to all industry. Even within a single company, diversified products prevent the setting of a single inventory-turnover ratio.

There are a number of other financial norms useful in analyzing

performance, such as the ratios of net sales to tangible net worth, net earnings to tangible net worth, inventory to net working capital, etc. Presumably, each of these criteria serves a useful function in helping compare performance with some sort of standard. While these financial norms are primarily for the benefit of the investor, they also serve to differentiate the more and the less effective industrial organizations.

SIGNIFICANCE

This concluding chapter of Part One serves to tie together the preceding nine aspects of management. Chapters 1 and 2 dealt with the broad concepts, objectives, and principles of industrial management. Stress on scientific management led to a consideration in Chapters 3 and 4 of two environmental factors: the prevailing technological level and the degree of standardization. Chapters 5 and 6 were visualized as the basic instruments or means by which group endeavor is integrated. These fundamental means include organization structure, its leadership caliber, and the attitudes and competency of its personnel. In Chapters 7 and 8, the importance of decision making, and specifically of mathematical analysis in scientific management, was studied. Finally, Chapters 9 and 10 described the significance of control in effective organization. There is a nexus, then, tying together:

1. The general aspects of industrial management (Chapters 1 and 2)
2. The environmental factors (Chapters 3 and 4)
3. The specific basic means available (Chapters 5 and 6)
4. The decision-making process (Chapters 7 and 8)
5. The exercise of adequate control (Chapters 9 and 10)

There seems to be no reason to justify debating the primacy of any one of these fundamental considerations. They are all integral parts of the thought-performance sequence by which:

1. A specific course of action is decided upon.
2. The necessary physical means are obtained.
3. Other individuals are convinced to assist in the performance of the requisite tasks.
4. Supervision is exercised so that the job is properly accomplished.
5. The product of the joint venture is equitably apportioned.

The preceding description is simply a rephrasing of the basic definition and description of industrial management as expressed on the opening page of Chapter 1. While all components of the managerial process are vital, it must be pointed out that, lacking adequate criteria for evaluation, the very purpose of scientific management becomes ephemeral and uninspiring. Thus, in summary, it seems expedient to state that performance measurement is the vital link between action

and satisfaction. Unless the specific action taken to accomplish a predetermined objective yields adequate satisfaction in terms of an accepted norm, there will be no stimulus to spark the group into cooperative venture. Lacking this unity of purpose even the biggest, richest, and oldest organization will disintegrate into a hodgepodge hegemony of vested interests and quasi-autonomous units pulling in divergent directions. The net result is chaos, the very antithesis of order and sound organization.

ILLUSTRATION 1. "Water Boy" [2]

"The dominant theme of Soviet rail transport policy," writes one Russian expert in the jargon so dear to experts, "has been that of maximizing the volume of services provided while devoting the minimum possible amount of resources to them." As freight traffic manager on the Vladivostok section of the Trans-Siberian railway, Comrade Vorobiev was a man with a mission to fill, and the imagination to overcome obstacles. His job was to move a specified tonnage of freight. But what if there was not enough freight to move? The latest issue of *Gudok,* the Soviet railway journal, tells how Comrade Vorobiev met his problem.

In 1955 Traffic Manager Vorobiev's line was in grave danger of falling below its monthly norm in tank-car loadings. Desperate for something to transport, and finding no petroleum, alcohol, milk or other useful liquid available, Comrade Vorobiev gazed about him, cast his eye on the glint of liquid in a nearby river, and, quick as a flash, filled 50 of his cars with water, sent them rattling off from Voroshilov. At a siding on the Trans-Siberian line, the water froze solid in the cars and it took a month for workmen to chip it out with pickaxes. But no matter—Vorobiev had made his quota.

Last May an even more desperate crisis loomed. Comrade Vorobiev was short of his quota by 150 tank-car loadings, and only two days were left to fulfill it. Vorobiev ordered out all his reserves. Old pumps were repaired, new waybills filled out. "Within a matter of hours," according to one eyewitness of the heroic affair, "an entire lake was standing on wheels in the freight yard." Vorobiev had done it again. Unfortunately, when the cars were unloaded, the sudden cataract released over the tracks washed away a good part of the roadbed. But who could deny that Comrade Vorobiev, reliable as ever, had met the norm?

QUESTIONS

1. Comment on Comrade Vorobiev's fulfillment of production norms.
2. What are some of the basic factors to be considered in the use of performance norms?
3. Mention some instances in our own economy where the Vorobiev mentality prevails.
4. Could this episode be termed typical of all production planning?

[2] *Time,* July 29, 1957.

ILLUSTRATION 2. Lineal Extension of Profit

Exhibit 10-8. Performance Data, International Harvester, 1945–1956

	Net sales	Net income	Net worth
	(in millions of dollars)		
1956	1,252	43.9	680
1955	1,166	49.8	662
1954	994	30.6	634
1953	1,256	46.2	621
1952	1,204	50.0	599
1951	1,277	57.2	570
1950	943	61.0	533
1949	909	55.5	493
1948	946	50.0	460
1947	741	42.7	431
1946	482	16.6	410
1945	622	18.7	406

QUESTIONS

1. From the data in Exhibit 10-8, show diagrammatically how an administrator might project a curve depicting the lineal-extension-of-profit concept.
2. How would you interpret the curves?
3. On the basis of the data presented, what cautions should be expressed relative to the lineal-extension-of-profit concept?
4. Assuming a valid projection of the profit curves, how might scientific administration be facilitated?
5. Is there any advantage in using sales data versus investors' equity as the basis for computing the lineal extension of profit?

ILLUSTRATION 3. Some Basic Industrial Measurement Norms

The data in Exhibit 10-9 refer to three measures of industrial performance.

QUESTIONS

1. Translate these data into graphic form.
2. Does there seem to be any relationship in trends?
3. How do you account for some of the discrepancies in trend lines?
4. Can you suggest some "overlooked" aspects relative to productivity which would tend to underestimate the figures of this index?
5. Using library sources, show, in graphic and tabular form, how productivity has varied over a twenty-year period in a specific industry.

Exhibit 10-9

Estimated year	Gross national product (billions)	Industrial production 1947–1949 = 100	Productivity per manhour 1947–1949 = 100
1957	$434.3	143	139.1
1956	412.4	143	133.6
1955	390.9	139	130.3
1954	360.7	125	125.2
1953	363.2	134	119.3
1952	345.4	124	115.9
1951	328.2	120	111.7
.	.	.	.
.	.	.	.
.	.	.	.
1935	72.5	47	85.3
1934	65.0	40	81.8
1933	56.0	37	79.8
1932	58.5	31	73.3
1931	76.3	40	76.5
1930	91.1	49	76.6
1929	104.4	59	76.7

SOURCE: *Moody's Industrial Manual,* Moody's Investors Service, Special Features Section, New York, 1958, p. a2.

ILLUSTRATION 4. Top-level Profit Motivation

Exhibit 10-10 shows the hypothetical proportions of the "profit pull" motivating top-level management in organizations categorized as to predominant type of directorate.

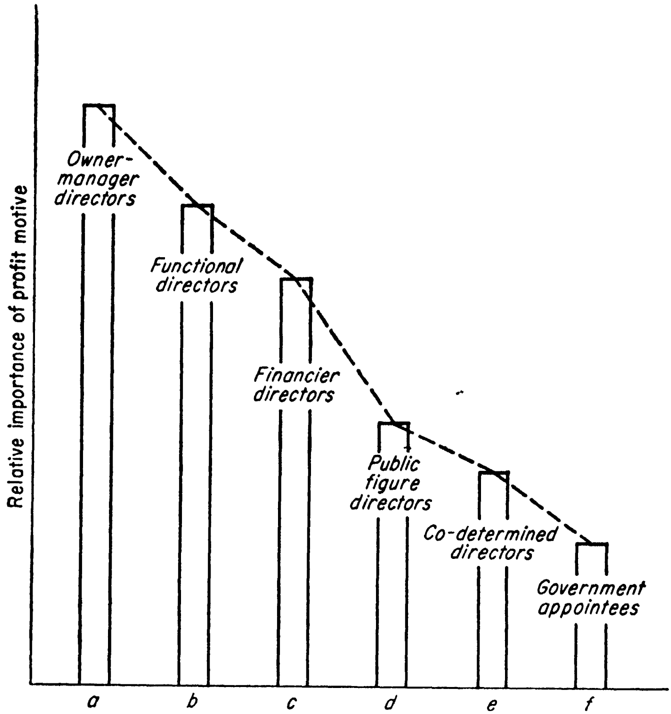
QUESTIONS

1. Does this seem to be an accurate presentation of relative degree of profit motivation?
2. What factors might account for this sharp decline in profit motivation from category *a* to category *f*?
3. Is profit the best or the only gauge to be used in comparing performance?

ILLUSTRATION 5. Transition—Concepts to Practices

The 10 basic concepts analyzed in Part One are integral to an understanding of the reasons for industrial organization. These and related concepts, together with what have generically been termed corollaries, collectively constitute the milieu within which human beings seek to satisfy their economic wants through group action. If the advantages

Exhibit 10-10



and limitations of a specific milieu are not properly comprehended, it is highly unlikely that a given group will utilize its full potential in organized effort.

Concepts, together with principles, laws, philosophies, and policies, provide a symmetry in action. The "why" underlying and initiating group endeavor must be understood and accepted prior to the inception of organization. Concepts and related norms give this rational basis by providing answers to the pertinent "whys."

Too frequently these "why" aspects are viewed as abstract and of interest only to the theorist. Such reasoning is patently specious since it is these "why" aspects which always condition and control the manner in which organized actions are to be carried out. For example, in an environment inimical to free enterprise, innovation will tend to be less frequent and of a lower order. A drying up of innovation will mean that new methods, products, equipment, and materials will not be forthcoming. Thus techniques are "frozen" because of an environmental factor, that is, a hostile attitude toward the concepts of tech-

nological change and free enterprise. Contrariwise, a more favorable attitude toward free enterprise will generally stimulate innovation and technological change, producing an attitude of dynamism and optimism together with more effective organization.

In contrast to concepts and principles which deal with the "why" aspects, techniques and practices are concerned with the precise manner as to how objectives are to be reached. Techniques and practices are thus analogous to blueprints which give in detail instructions as to dimensions, qualities, and methods of performance. Invariably, blueprints must conform to prescriptions set by basic concepts and principles. For example, if a new home is being planned, it is first imperative to decide upon the basic style, which might be contemporary, colonial, etc. The blueprint will then detail construction methods, materials, dimensions, and design in accordance with the basic idea, style, or principle selected. A blueprint not only prescribes the specific method to be followed, but by its very prescription of means imposes rigid controls upon performance. In this context the blueprint practices and techniques studied in Part Two are actually ways of controlling industrial activity so that maximum efficiency results. Consequently, each of the following chapters could be designated as the *control* of a specific industrial function such as cost, methods, quality, or manpower. These practices and techniques should be viewed as immediate controls operating within a broader framework of more remote controls imposed by concepts, principles, and philosophy, all of which condition the attainment of a given objective.

The propagation, transference, and acceptance of ideas involving concepts and principles is a slow process. Considerable indoctrination is necessary. Probably the most effective device for selling this level of ideas is the narrative-descriptive method employed in Part One. Techniques, however, seem to be best learned by observation and actual doing. This basic difference necessitates a change in the chapter structure in Part Two. Less stress will be given speculation and broad overall considerations. The sections on development and significance will be omitted since they would entail lengthy and tedious analyses. The corollaries will be replaced with a section on the more important specific techniques currently in use. More of the illustrations will be of an arithmetic and graphic form.

Although Part Two will be more in the nature of a pragmatic approach in contrast to the conceptual analysis of Part One, it is important to stress the indivisibility of industrial management. It is not enough to speculate about why certain management ideals are neces-

sary. Neither is it adequate to learn how to perform even the most skilled operations without trying to understand how they fit into a logical scheme. Modern industrial management cannot utilize at the managerial level the services of the detached visionary or the dedicated mechanic. A good industrial manager must be a composite of both.

PART TWO

Techniques

CHAPTER 11

Capital-Equipment Utilization

DEFINITION AND DESCRIPTION

The term *equipment* generally refers to a material object fashioned by man for future use in facilitating men in the production of goods and services. At first glance this rather broad definition would seem to encompass not only the many categories of machinery generally associated with the term *equipment,* but also all tools, buildings, and even some goods-in-process. Because of the confusion which can so readily arise out of this terminology, it might be appropriate at this time to differentiate between (1) capital goods, (2) consumer goods, and (3) services.

The last category refers to acts of labor performed by one person for the benefit and satisfaction of another person. The usefulness of this service is not fundamentally associated with an object, but rather with a talent possessed by the one performing the service. Instruments, tools, materials, and a work place can be involved in the fulfillment of this service. These objects are, however, secondary to the basic service itself, which is generally assumed to be intangible, ephemeral, and flowing from the character and competency of the one performing the useful function.

In the two classifications of goods, material items possessing utility are classified according to the immediacy with which they can be put

into use to yield satisfaction. Thus consumer goods are assumed by definition to have the attribute of providing want satisfaction almost at the possessor's will. There is no need, assuming the consumer good is in its finished form, for further conditioning. This caution is inserted so that a proper differentiation will be made between finished products and goods still in process. Another important aspect is the gradual or immediate destruction of the good through the want-satisfying act. There is no general agreement as to when this annihilation of the good, either in form or in function, must take place. As a consequence, some consumer goods are labeled nondurable while others are classified as durable. This attribute of durability in economic goods might be pictured as the power of that object to yield a succession of utilities over a period of time. While the factor of durability is probably not adequate as a single criterion for rigid differentiation among consumer goods, it is very commonly used.

Durability, to an even greater degree, is associated with capital goods. It is the function of capital goods to perform an intermediate function in the production of consumer goods which, in turn, have a more immediate power to satisfy wants. This premise is usually set forth in all basic economics texts under the discussion of the familiar concept of "roundaboutness." Briefly reviewing this concept, it is almost universally assumed that among the attributes differentiating man from the lower animals is man's propensity to fashion implements, tools, gadgets, machines, that is, manufactured devices by which actions and satisfactions are maximized. No other living creature has the foresight to visualize that through this intermediate phase a means is created for increasing the ultimate utility many times over. This, in essence, is the fundamental thesis of roundaboutness and the rationale for capital goods and equipment.

Once again the temporal factor enters into the analysis. Some of the items pertinent to roundaboutness are very rapidly used up in the productive process. Others must be used many times and over a long period of time before their usefulness has been exploited to the maximum. Just as consumer goods can be classified as durable, semidurable, and nondurable, so too, capital goods can be separated on a comparable basis. Machinery is obviously a durable form of capital goods. The broad category of tools has a much shorter productive life span and might be labeled semidurable. Some tools and most incidental items, called supplies, consumed after a single or only a few applications, might by analogy be considered as being nondurable since they possess only a short-term usefulness.

At this point it seems appropriate to summarize this aspect by stating

that the purpose of all economic goods and services is to provide want satisfaction. Economic goods, in the consumer category, are immediately available for fulfillment of the basic function. Items in the capital-goods category, however, are not themselves directly or immediately available for satisfaction of consumer wants. Instead, the capital goods are used to fabricate raw materials into consumer goods. Thus capital goods are one or more stages removed from the direct and ultimate consumer-want-satisfying phase.

A better comprehension of capital goods in general, and equipment in particular, hinges upon the interpretation given the following aspects:

1. Function and types of equipment
2. Capacity
3. Progressive deterioration
4. Capital recovery

Function and Type. Capital equipment in the more restricted sense pertains primarily to machinery, that is, power equipment used to transform materials into semifinished or finished products. Even a basic acquaintance with the subject should be sufficient to emphasize that the classification of machinery includes a tremendous diversity of items varying as to function, size, cost, shape, component parts, etc. An adequate differentiation on all important characteristics would be a mammoth undertaking.

Industrial equipment is frequently classified as either general purpose or special purpose. The former, as its name implies, includes the type of equipment which can, with minimum adjustment, be used for a variety of purposes. Most standard machine tools have this flexibility. Thus an engine lathe can be used to fashion a great variety of different products. General-purpose equipment can also be added to or removed from a specific process sequence with comparative ease. Frequently general-purpose equipment is grouped into what is familiarly known as functional, or process, layout. In such an arrangement, machines with like functions are grouped into a specific department to which are ascribed certain processing activities.

The very term *special-purpose equipment* implies limited use, inflexibility, more intricate construction, and more detailed planning prior to installation. In a sense, special-purpose equipment is an adjunct of large-scale manufacturing. When large quantities of product are to be processed, it becomes more feasible to utilize a machine's entire capacity exclusively for a single operation. At that point the decision maker must determine whether or not it would be desirable to replace a general-purpose machine which has been allocated to

performance of a single operation with a special-purpose piece of equipment. There are obvious advantages and limitations. In addition to the so-called inflexibility, special-purpose equipment tends to be costly and subject to rapid obsolescence. Bottlenecks can easily follow the breakdown or improper scheduling of this type of equipment. Changes in product can necessitate costly adjustments in the special-purpose machine. Diminished demand for the product generally means idle capacity since this equipment can rarely be put to other use. This distinction between general-purpose and special-purpose equipment is, of necessity, summary in character. A more detailed differentiation would be extremely time-consuming and of minimal value for this type of text.

Capacity Calculation. In generic and nontechnical terms, capacity is simply the ability of an individual, an organization, or a piece of equipment to be of service in the performance of acts requisite to the attainment of predetermined objectives. Capacity, then, is merely the ability to produce. Some of the aspects pertinent to individual and organizational ability to produce have already been discussed in previous chapters. In this section attention is focused upon capacity inherent within a given unit of industrial equipment to perform specified functions under prescribed conditions. In some respects, calculation of equipment capacity is a simple matter as compared with determination of individual and organizational ability to produce. As was previously stressed, the subjective factors entailed in human and organizational activities present so many complex and volatile variables that analysis frequently approximates conjecture. With equipment, however, there are no inherent subjective forces.

While it is obvious that the actual or realizable capacity of a machine is subject to factors such as the operative's competency, the operative's attitudes, maintenance policies, control of materials, scheduling practices, and similar variables, it is still possible and desirable to estimate the ability of a particular machine to perform its stated function. Since there are numerous functions performed by machines, it is practically impossible to use a single yardstick in measuring capacity. For example, one of the basic functions of a machine tool is to remove metal by a chipping action. Chip pressure in pounds is one means by which a machine's potential can be measured. A simple and relatively accurate formula, $P = CA$, has been developed for such measurement. P, in this instance, equals chip pressure in pounds; A is the sectional area of the chip in square inches, determined by the depth of cut times the feed per spindle revolution; C is a constant value varying only according to the material being processed.

While this type of capacity calculation has meaning in so far as chip pressure is concerned, obviously this and similar norms have no value in measuring capacity of equipment in general or even for a significant segment of the equipment category. Although certain more universal norms, such as horsepower, revolutions per minute, etc., are commonly used, they too provide only a rough approximation of machine capacity.

Individual differences in machines, as in men, make measurement complex and of limited value. Consequently, the decision maker must make proper and judicious allowances and modifications where deemed expedient in determining a specific unit of equipment's potential to produce. While measurement of the mechanical aspects might yield one set of presumably attainable capacities, the force of circumstance must always be reckoned with. Thus when the engineers establish that a given mechanism is capable of so many revolutions per minute, or strokes per second, or pounds pressure per square inch per minute, there are still numerous conditioning forces which must be considered. In particular, adequate maintenance, scheduling and routing practices, quality of material being processed, level of performance at the immediately preceding and the immediately following work stations, the force of custom, absolute and relative cost considerations, level of demand, legal considerations, and many other factors exert modifying pressures. The prudent decision maker must of necessity make adequate allowances for every important variable which conditions a machine's rated potential.

Progressive Deterioration of Equipment. There are two basic forces which lead to deterioration in equipment. Depreciation is the physical wearing away of a machine brought about by use and the disintegrating effect of time and the elements. Obsolescence is the economic and, in some respects, the psychological decrease in a mechanism's value resulting from shifts in needs and wants of those who could use that equipment's services. In an economy characterized by technological maturity, where change is at a minimum, obsolescence is of minimum importance. A piece of equipment under such circumstances would tend to be useful as long as it was physically capable of operation. In a dynamic economy, on the contrary, the factor of obsolescence can put an end to a machine's service life even before that equipment has been installed. For example, the very real possibility of obsolescence has deterred some managements from embarking upon more extensive automation. The reasoning is evident. Too hasty an investment in the extremely costly automated equipment can have serious consequences if technological developments were to outmode the equipment before

the concern had an opportunity to recover its investment. Antiquated Federal legislation pertinent to depreciation policy for taxation purposes is an extremely important factor in this regard.

Since obsolescence is basically the product of extraneous and subjective forces, measurement of equipment deterioration in this respect is largely a matter of sound judgment. Despite the adamant resistance, by tax authorities, to accelerate write-offs of equipment cost resulting from obsolescence, the decision maker must record at least a mental note of this factor. In most cases the historical experience of that concern and the particular industry should provide at least an approximation of anticipated obsolescence. The prudent decision maker will bear in mind, however, that technological change rarely occurs in a gradual and measurable pattern. Thus an intimate knowledge of the industry, its structure, function, technological level, and potential, is vital for sound decision making as to equipment utilization.

Depreciation, unlike obsolescence, is more readily measurable. For example, as a unit of equipment is subject to use, wear and tear are invariably reflected in its performance. A deceleration of tempo, more frequent breakdowns, poorer quality of product, and related negative features become more and more apparent. This gradual deterioration can be arrested somewhat by adequate maintenance, and particularly by the incorporation of technological improvements through progressive modernization programs. While wear and tear are logically associated with use of equipment, there are several factors which tend to maximize depreciation. Improper maintenance has already been alluded to. In addition, multishift use tends to wear out equipment at a disproportionate rate. Frequent changes in operatives likewise have deleterious consequences. Poor supervision, use by apprentices or improperly trained employees, lack of a preventive maintenance program, and frequent changes in setups are among other negative circumstances.

Even though many of the variables affecting depreciation do not occur in regular or symmetrical patterns, most depreciation methods are based on strict arithmetic or geometric progressions. The most commonly used methods include:

1. Straight-line
2. Reduced-balance
3. Sum-of-the-year's-digits
4. Machine-hour
5. Quantity-of-output

The straight-line method is very commonly used in all areas of business and industry. The very simplicity of this device is its greatest advantage. For example, a machine purchased for $10,000, with a life

expectancy of 15 years and a salvage value after that period of $1,000, would be depreciated as follows: ($10,000 – $1,000)/$N$ = $9,000/15 = $600 depreciation to be written off annually. If salvage value is negligible or cannot be estimated, the computations exclude this consideration. Despite its widespread acceptance, there is serious objection to this method. Charging a constant sum to depreciation over the entire life of the asset does not seem to conform to reality in most industrial situations.

The reduced-balance method provides for a steadily decreasing depreciation. This and the following technique are postulated on the conviction that there should be a disproportionately heavy loss in the equipment's value in the first few years of useful life. This premise might be based upon the expectation of rapid obsolescence, the need for a safety factor, or comparable reasons. In substance, the reduced-balance method employs a constant percentage which is deducted from a base which dwindles each year. Thus a $5,000 purchase, with a 10 per cent depreciation rate, would yield $500 depreciation the first year. The following year, the 10 per cent is computed on the $5,000 – $500, or $4,500 base. Depreciation for the second, third, and fourth years would amount to $450, $405, and $364.50, respectively. While this technique allocates the major portion of equipment cost to the early years of equipment use, there is an objection in that to the last few years of use can be ascribed a practically negligible depreciation.

The sum-of-the-year's-digits method is comparable to the preceding technique. The prime difference is the substitution of a variable multiplier in place of the constant percentage. This multiplier is obtained by adding the digits representing the expected life of the equipment. This sum becomes the denominator in the multiplier. The numerator is the digit representing, in reverse order, the life of the equipment. For example, if a $5,600 asset has a life expectancy of 7 years, the depreciation computations would be as follows:

Years	Multiplier	Depreciation
1	7/28 × $5,600 =	$1,400
2	6/28 × 5,600 =	1,200
3	5/28 × 5,600 =	1,000
4	4/28 × 5,600 =	800
5	3/28 × 5,600 =	600
6	2/28 × 5,600 =	400
7	1/28 × 5,600 =	200
28		$5,600

The machine-hour method, as indicated by the name, attempts to allocate depreciation strictly on the basis of use. The first step in this procedure is to calculate the probable number of hours that the equipment can be used, assuming normal maintenance, before it must be scrapped. With this as a base, and knowing the exact number of hours that a piece of equipment was used during a given accounting period, depreciation can be computed by a simple arithmetic process. If a specific machine is estimated to have a useful life of 15,000 hours and it was used 3,000 hours during the year in question, then depreciation charges for this year should be set at 20 per cent of the equipment's cost. This method has some very obvious advantages. It is realistic since costs are written off as they are incurred. This minimizes the illogical practice of writing off equipment in equal installments during periods of prosperity and periods of depression. In the latter, costs can be exorbitantly inflated because of this inequitable procedure. The machine-hour method, once the life of the equipment has been properly estimated, is very simple to administer. As with all looking into the future, there is, however, the real danger of inadequate estimates.

The quantity-of-output method is very similar to the machine-hour method in that actual use of equipment is the basis for depreciation. As mentioned in the preceding technique, this tends to result in more realistic cost figures. Output, in this instance, can be measured in specific units of production such as ingot tons, pairs of shoes, loaves of bread, etc. Sales volume can also be used as the norm, although it has certain disadvantages, especially during inflationary periods. The specific number of jobs or of orders can likewise be employed as the base. In every instance, experience rather than an arbitrary measure sets the depreciation rate.

Depreciation policy is not a matter set exclusively by management. Since corporation profits taxes can be significantly affected by the particular depreciation policy in force, governmental taxing agencies keep a watchful eye on corporate policy and practice relative to depreciation. There has been considerable agitation in recent years to modify existing legislation relative to the write-off of equipment for tax purposes. It has been stressed that in this country equipment generally is amortized over fifteen or twenty years. On the other hand, many other countries have far more liberal tax provisions. Sweden and Canada allow five-year write-off periods. France and Italy permit seven-year periods.

One of the consequences of our ultraconservative tax policies is the relative obsolescence of much of our industrial equipment. Since 1925 the *American Machinist* has been making periodic surveys of the age

of our industrial equipment. The most recent study seems to indicate that almost three-fourths of all equipment used in American industry is at least ten years old. In 1959, this category of relatively old equipment comprised 74 per cent of all equipment. The record high, up to the recent census, for old equipment in use was reached in 1940, the period immediately after the money-tight depression era, when 72 per cent of all industrial equipment was ten or more years old. To students of scientific management and to all individuals who are cognizant of the benefits of dynamic mechanization, the continued use of obsolescent and antiquated equipment should clearly indicate industrial retrogression.

Capital Recovery. The concept of roundaboutness, mentioned previously, is applicable to all types of equipment. Roundaboutness implies both investment and futurity. There is a series of costs associated

Exhibit 11-1. Compound-interest Factors: Compound Amount

Years	Rate of interest					
	4	5	6	7	8	10
5	1.217	1.276	1.338	1.403	1.469	1.611
10	1.480	1.629	1.791	1.967	2.159	2.594
15	1.801	2.079	2.397	2.759	3.172	4.177
20	2.191	2.653	3.207	3.870	4.661	6.727

with the deferring of utility from the present to the future. There is an opposite series of benefits which follow such deferment. The benefits of the roundabout action which produces the equipment, however, can be extracted from that equipment only with usage and the passing of time. Consequently, $1 invested today in a piece of equipment should be worth more than $1 one year from today. With a compounding of interest the same dollar should be worth much more at the end of a period of ten or twenty years. Precise measurement of such future worth is made easy through the construction of special formulas and detailed tables. The rate of interest has an obvious bearing upon these computations. Exhibit 11-1 lists the anticipated return from each dollar invested, at specified interest rates and over selected time periods. Thus $1 invested today at 6 per cent would be worth, by annual compounding, $2.40 in 15 years. At 10 per cent and for a 20-year period, the same dollar should increase in value to $6.73. Given the interest rate and the time period this technique permits capitalization of costs for any size of investment. It might be interesting to note that

a \$1 investment at 10 per cent compounded annually for 100 years yields a sum of \$13,780.61.

Another view of capitalized cost of equipment can be had by converting the return into present worth. This procedure is based upon the premise that \$1 collected in the future has a present worth discounted for the appropriate time period and the selected interest rate. Thus, if the interest rate is assumed to be 4 per cent, then \$1 to be received 20 years hence has a present worth of only \$0.456. At a 10 per cent rate of interest, \$1 recovered in 20 years has a present worth of only \$0.149.

Both these aspects of capitalized cost, the compound amount and the present worth, have important bearing upon equipment purchase, utilization, and replacement. Other terms frequently used in connection with depreciation include book value, scrap value, and present-market or actual-disposal value. Book value pertains to the theoretical

Exhibit 11-2. Compound-interest Factors: Present Worth

Years	Rate of interest					
	4	5	6	7	8	10
5	0.822	0.784	0.747	0.713	0.681	0.621
10	0.676	0.614	0.558	0.508	0.463	0.386
15	0.555	0.481	0.417	0.362	0.315	0.239
20	0.456	0.377	0.312	0.258	0.215	0.149

sum of value remaining in an asset after customary allowances for deterioration have been made in proper accounting fashion. Evidently unless there is a perfect correlation between the actual physical and economic decline in the asset's value and the allowance provided by the company's depreciation policies, book value and actual value are not identical. Disposal value, as the term implies, is the sum recoverable from the sale of an asset presumably for use in a lower-level function. If the asset has no further economic function, then its value is determined by what it will sell for as scrap. The important distinction that must constantly be kept in mind is that between book value and disposal value. There is little comfort in the knowledge that a piece of equipment which would sell for only x dollars has a book value of $2x$. Actually, an inflated book value, in addition to being unrealistic, can prove to be most embarrassing if an exchange or disposal of the equipment is mandatory.

The capital-recovery rate is a commonly used yardstick helpful in formulating decisions as to the feasibility of equipment replacement.

For example, a specific challenger requiring a net investment of $10,000 has a combined annual-operating and capital-cost advantage over the respective defender of $3,000. If the new equipment has a life expectancy of 20 years, with no salvage value at the end of that period, depreciation by straight-line method would amount to $500 per year. Thus at the end of the first year the asset would have a book value of $9,500. However, assuming that the $3,000 savings were directly applicable to the investment, then the $9,500 minus $3,000 leaves only $6,500 to be recovered over the remaining 19 years of the equipment's service life. The following year, deducting $500 depreciation and assuming a constant $3,000 saving applied to capital cost further reduces the investment still to be recovered to only $3,000. Thus, in slightly less than three years, the entire $10,000 investment has been recouped. The pay-off period of approximately three years would seem to be ample justification for purchasing the machine. It is possible under extraordinary circumstances where the impact of obsolescence is particularly severe that the capital-recovery period will be set at less than three years. Normally, however, a three- to five-year capital-recovery period seems to be defensible. It is the function of the policy makers to decide on the appropriate capital-recovery rate. In addition, the policy makers must ascertain what variables are important, how the effect of each variable is to be measured, and what alternatives are to be considered.

In addition to the items discussed in this section, there are a number of other very important aspects associated with equipment purchase, utilization, and replacement. Many of these subjects, since they are equally or even more important to other production functions, have been relegated to other sections of the text. For example, utilization of equipment is distinctly part of the production control function. Work measurement, including both the methods-analysis and time-study techniques, is intimately connected with the efficient use of equipment. In fact, it is practically impossible to divorce the many ramifications of equipment usage from any of the fundamental management concepts and techniques. Gantt charting, process flow charts, calculation of economic lot size, quality control, job descriptions, and every other adjunct of effective industrial organization are directly affected by corporate policies dealing with equipment acquisition, usage, and disposal.

TECHNIQUE 1. Economy Study—Tabular Technique

Probably the easiest and most comprehensive device for comparing the relative merits of two different units of equipment is to list the

demonstrated or estimated respective costs in tabular fashion. Comparative costs, in total and for each cost component, are set down in parallel fashion. The relative difference in each cost category indicates a particular machine's advantages or limitations. In every instance the decision to retain the equipment presently in use or to replace it with more efficient substitutes should be based upon the comparative advantages of the respective mechanisms.

Fundamentally, all economy studies pertinent to equipment utilization or replacement are merely analyses of the superiority of one form of mechanization over a less advanced type of mechanization. The cost balance is consequently subject to two diverse pulls. Invariably the new method tends to lower direct labor costs but increases capital costs. When the new equipment requires considerably more adjustment and supervision by a higher grade of worker, indirect-labor costs also tend to be higher. As with all mechanization, then, the basic decision is to determine at what point the costs of the increased investment required by the more mechanized method make change uneconomic.

The following is a simple illustration of the basic principles of replacement economy.

A proposal has been made to replace a twelve-year-old standard typewriter with a new electric typewriter. Assuming that (1) the new equipment would permit a 20 per cent increase in output, (2) typists are paid an average rate of $1.70 per hour, (3) qualitative differentials are estimated as a 10 per cent advantage for the new equipment, the new equipment, with an assumed life span of ten years, would cost $360. The old equipment originally cost $160 and has a present value of $25. Interest charges are set at 10 per cent.

At first glance the total cost of the new equipment ($3,817) would seem to be somewhat higher than total costs with the present method ($3,787.50). However, proper adjustments must be made to account for quantitative and qualitative differences whenever they are important. Obviously, if in this instance a total output of 10,000 units (letters, bills, memoranda, etc.) constituted total demand, then the quantitative differential might have minimum significance. However, assuming that this concern can utilize the greater and better output, then the attainment of the 13,000-unit equivalent would cost 30 per cent more by the old method. The equivalent cost of the old method would then be $3,787.50 + 0.30($3,787.50), or $4,923.75. Thus the substitution of the electric typewriter would mean a saving of $1,136.25 for a one-year period. Since the new equipment costs only $360, the entire investment would be recovered in about one-third of a year. The decision

to replace the twelve-year-old typewriter should almost be a certainty under these circumstances.

However, as has already been implied, if there were no need for the extra capacity afforded by the more efficient electric typewriter or if the quality differential of +10 per cent were unwarranted, there might be no justification for replacement. In this instance, as in practically all such studies, the rationale for change comes from the assumption that direct-labor costs will be lowered through the equipment-replacement process. Even the qualitative differential might be viewed in terms of direct labor since it can be assumed that to attain a comparable quality

Exhibit 11-3

	New typewriter	Old typewriter
Direct labor (2,000 hours)	$3,400.00	$3,400.00
Equipment cost:		
Depreciation, etc.	36.00	5.00
Interest	36.00	2.50
Insurance, etc.	20.00	10.00
Maintenance	5.00	10.00
Materials and supplies	320.00	360.00
Total	$3,817.00	$3,787.50
Units of output	10,000	10,000
Quantitative advantage (20%) +	2,000	
Qualitative advantage (10%) +	1,000	
Total	13,000	10,000

provided by the new method, the worker on the old equipment would be forced to spend an additional 10 or 12 per cent more time to produce a comparable product. If the improved quality is of incidental consequence, then this advantage of the new equipment likewise loses significance. Similarly, assumptions as to the rates of depreciation and obsolescence, the space savings, interest changes, etc., can easily modify conclusions. The decision maker must therefore be acquainted with all pertinent facts. The estimates he makes are only as reliable as the data upon which they are based.

The preceding is a summary presentation in tabular form of a simple cost comparison between a unit of equipment presently in place and a proposed replacement. There are numerous modifications and elaborations upon this basic technique. One of these versions is pre-

sented in the Cincinnati Milling and Grinding Machines Company's replacement analysis form described in illustration 1.

Another well-known device is that described by Alford and Bangs.[1] This technique, although it uses letters of the alphabet to designate pertinent factors, is not actually an algebraic presentation. The alphabetic approach does, however, lead to conciseness in presentation and to a greater facility in showing cost interrelationships. In this method:

I = Investment in present or proposed equipment. For proposed equipment this should be total cost in place ready to operate, and for present equipment it should be present net realizable value, regardless of book value.
A = Annual percentage allowance for return on invested capital.
B = Annual percentage allowance for taxes, insurance, etc.
D = Annual percentage allowance for depreciation and obsolescence [capital recovery omitting interest].
C = Annual total cost (in dollars) of upkeep and/or maintenance.
E = Annual total cost (in dollars) of power, supplies, etc.
F = Annual total cost (in dollars) of space allotted to machine.
M = Annual total cost (in dollars) of material.
L = Annual total cost (in dollars) of direct labor.
T = Annual total cost (in dollars) of indirect labor.
Y = Annual total fixed charges (in dollars), $Y = I(A + B + D)$.
R = Annual total charges (in dollars) of all kinds against machine for producing expected output.

$$R = Y + C + E + F + M + L + T$$

The logic, conciseness, and symmetry of this technique are best expressed by means of a practical application. In a given case (Exhibit 11-4), it is proposed that a twelve-year-old Cincinnati No. 4 Vertical Miller, with a present disposal value of $9,400, be replaced with a Cincinnati No. 5 Vertical High Power Miller costing $25,500 when installed. The figures listed in the first column of the illustration pertain to the specific costs attributable to the present equipment. The center column contains the symbol for the important cost factors. Incidentally, this list can readily be expanded or contracted as expediency dictates. The last column contains the comparable costs estimated for the proposed replacement.

While the several cost categories and the respective figures seem to be self-explanatory, it might be expedient to call attention to several important items. The depreciation and obsolescence factor D, while subject to Federal tax regulations, can nevertheless be modified as circumstances warrant. Thus a prudent decision maker would, for this

[1] L. P. Alford and J. R. Bangs (eds.), *Production Handbook*, The Ronald Press Company, New York, 1955, p. 841.

type of calculation, lower the estimated life span of the new equipment if he believed significant pertinent technological changes were taking place. This arbitrary action, while not permissible for tax computations because of the inflexible Federal tax structure, would nevertheless mean that the decision maker should consider, in his "private" calculations, a much higher allowance for the depreciation and obsolescence factors.

Similarly, in each of the cost classifications, necessary modifications must be made whenever the decision maker deems them to be judicious. In this particular example, the materials cost M reflects only the

Exhibit 11-4

Present equipment: Cincinnati No. 4 Vertical Miller	Symbol	Proposed equipment: Cincinnati No. 5 Vertical High Power Miller
$9,400	I	$25,500
0.12	A	0.12
0.03	B	0.03
0.20	D	0.20
0.35	$A + B + D$	0.35
$9,400 × 0.35 = $3,290	Y	$25,500 × 0.35 = $8,925
665	C	60
523	E	215
63	F	45
650	M (scrap)	110
7,655	L	3,799
4,390	T (set up, etc.)	1,120
$17,236	R	$14,274

loss incurred by spoilage of materials in process. Assuming no change in the processing rate, the actual cost of materials processed and accepted should remain constant.

In the labor-cost categories, direct labor presumably would be reduced in this instance because of the greater automaticity of the new equipment. As was mentioned previously, this reduction in direct-labor costs seems to be a concomitant of intensified mechanization. While the distinction between direct and indirect labor is spelled out by definition, there is an overlap which steadily widens with progressive mechanization. The costs of this indirect-labor increase or decrease, depending upon the degree of automaticity incorporated in the new equipment. In the illustration in question, there is a significant decrease in the cost of indirect labor, primarily because of the preparations antecedent to actual use of the equipment. However, under dif-

ferent circumstances, it is reasonable to assume that the more complex new equipment will require a higher level of mechanical ability to perform the more intricate setting-up and breaking-down sequences. Then too, production-control costs would undoubtedly rise. In either event, indirect-labor costs would behave in the opposite fashion to that shown in the preceding illustration.

On the basis of the difference in the combined operating and capital costs for the proposed equipment as compared with the costs of the present equipment, a saving of $2,962 would be effected in the first year. Thus the entire cost of the change would presumably be recovered in extra profits over a period of about eight years or less. Whether or not this recovery period is adequate depends upon the replacement policies established by the proper corporate decision makers. In this case, since the equipment is very durable and probably not susceptible to any significant technological change within the next decade, it would seem reasonable to assume that an eight-year or less recovery period is justifiable reason for installing the new equipment.

In summary, the tabular technique in its many modifications is very frequently used to compare the economy of using presently available equipment to the feasibility of the economy of investing in newer and better equipment. It is important to emphasize that in studies of this type every pertinent variable must be identified, segregated, and measured. As with most decision making in the industrial sphere, there is no one sure way to quantify the effect of every significant variable. Differences in opinion and in measuring technique inevitably lead to divergent views as to the proper equipment-utilization-and-replacement decision. Obviously, techniques such as the tabular method should help considerably by establishing a factual basis for more effective decisions.

TECHNIQUE 2. MAPI Method

George Terborgh, Research Director of the Machinery and Allied Products Institute, made an outstanding contribution to the theory of equipment replacement in the MAPI study "Dynamic Equipment Policy." [2] This work begins with the fundamental thesis that the connotations of the term *replacement* are distinctly inadequate for a dynamic economy such as ours. Terborgh stresses that terms such as displacement, reequipment, or remechanization might be more appropriate. The logic for this suggestion follows from the very practical consideration that even in the sphere of capital-equipment utilization

[2] George Terborgh, *Dynamic Equipment Policy*, McGraw-Hill Book Company, Inc., New York, 1949.

there is a never-ending competition between the existing equipment, alternate but comparable equipment, and new improved substitutes. In particular, the latter poses a problem in so far as the original equipment might not be anywhere near the point of ultimate physical collapse. This means that the original equipment, with proper maintenance and periodic rebuilding, is still capable of fulfilling its basic function. However, the new improved substitute presumably can do the same job in less time and at less cost. In addition, the proposed replacement generally has additional advantages such as greater capacity, increased flexibility, greater automaticity, etc. Terborgh's first premise, then, states that all equipment is "subject to the competition of improved substitutes, so that the quality of service may decline *relative to available alternatives* even when it does not deteriorate absolutely." [3]

Another premise emphasizes that replacement decisions should not be influenced by book value, that is, the portion of the original investment in that equipment which has not as yet been charged off according to the accounting system in use. The notion is held almost universally that the entire investment in the capital asset must be written off in orderly installments. Yet even a rudimentary acquaintance with depreciation policy is sufficient to realize that such symmetry and sequence as is generally associated with depreciation techniques is seldom in accord with real deterioration in that asset's value or service life. Nevertheless, the force of depreciation policy, as set by law and custom, exerts a powerful influence upon replacement practice, specifically by the release of reinvestment funds.

Functional Degradation. Terborgh uses this term to highlight the industrial practice whereby a piece of equipment, after it has outlived its usefulness in fulfilling its original purpose, is shifted to a secondary use. Demotion, or degradation, to fulfillment of a secondary function frequently prolongs the equipment's use indefinitely. This practice, however, complicates the accounting procedure requisite to proper allocation of the equipment cost to specific products and to specific accounting periods.

Functional downgrading can be either quantitative or qualitative in character. The former pertains to the decrease in the amount of service yielded by the particular equipment with the passing of time. The latter, as implied in the term, reflects a decline in level or kind of work assigned to that equipment. It should be added that buildings, materials, and even manpower are subject to both these forms of functional degradation. For example, many of the old textile mills in New Eng-

[3] *Ibid.*, p. 2.

land have become relatively obsolete from a quantitative-degradation point of view because the newer textile plants erected in the South have modern-plant-layout advantages built into them. Thus the old structure, because of antiquated architecture, cannot compete with the new mills on a quantitative basis.

Then too, many of the old-type textile-mill structures, instead of being abandoned, are converted to other uses. Very frequently new enterprises, particularly in the fields of plastics, metal fabrication, and electronics, have moved into these otherwise unused facilities. While from a value-added point of view the new industries might appear to be of a higher order than the original users of the mills, it should be emphasized that these new occupants are generally in the marginal category of their own industry. Invariably as the new enterprises establish themselves, they build, buy, or lease new and better buildings. This is qualitative functional degradation which ultimately leads to the relegation of the obsolescent structures to warehousing purposes, then to outright abandonment, and finally to demolition.

Operational Inferiority. Another important concept emphasized in the MAPI study is that of operational inferiority. This is derived from a careful comparison of present equipment with the best alternative currently available. It is obvious that in a technologically dynamic society new and better tools, equipment, buildings, and better-trained workers are constantly being introduced. Thus operational inferiority is a function of technological development as expressed in terms of depreciation and obsolescence. Although depreciation and obsolescence tables and formulas are available for measuring the hypothetical effect of time upon equipment service potential, the almost infinite combinations and permutations of variables affecting the situation frequently tend to reduce measurement of operating inferiority to the level of conjecture.

Adverse Minimum. Replacement of operationally inferior equipment inevitably necessitates financial capital expenditures. The concept of the adverse minimum emphasizes the fact that there is an onus attached to every alternative. It is the decision maker's job to determine which alternative yields the greatest advantage at the lowest possible combination of cost. To a degree the economic law of comparative costs resembles the concept of the adverse minimum. This stress upon costs, explicit and implicit, associated with alternative courses of action, is fundamental to all decision making. The use of the term *adverse minimum* merely injects an additional note of caution by calling attention to the fact that technological improvement does not

necessarily mean absolute and permanent cost or competitive improvement. The relativity of operational inferiority and of the adverse minimum in reference to the factor of time should be apparent. As every car owner so readily recognizes, there comes a time when he must decide whether the utility provided by his present vehicle, keeping in mind the rising maintenance costs, can economically be justified as compared with the greater utility which would probably accompany the purchase and use of a new car. If maintenance costs can be kept relatively low, each additional year's use of the old car means a longer period for prorating the initial investment. While very few purchasers of new cars actually calculate the comparative costs, there usually is a rational process by means of which the prospective new-car buyer attempts to determine the adverse minimum. In the industrial sphere it should be obvious that much more than simple reflection is mandatory in establishing the adverse minimum relative to alternative available equipment.

In Terborgh's work, the adverse minimum is associated with the "defender," that is, the equipment currently being used, and the "challenger," the alternative under consideration. Comparison of these adverse minima gives an objective basis for making decisions as to equipment utilization and replacement.

The Inferiority Gradient. With the passage of time even the most superior piece of equipment will tend to become relatively less efficient. The relative decline in operational effectiveness becomes compounded with the continued passage of time. This operational inferiority can be depicted graphically by the inferiority gradient, which simply reflects the operational gap, over a period of time, between the equipment in use and the best current alternative. Theoretically, if the best piece of equipment has been installed, then there should be no inferiority for the first time interval. However, within a relatively short period, a more efficient machine will almost certainly become available. In addition, wear and tear will tend to make the machine in use become less efficient. This differential between the defender's effectiveness and the superior performance of the challenger is the inferiority gradient. Terborgh proposes, for simplicity in analysis, that in the second year there will be a specific sum by which the challenger is operationally superior to the defender. In the third year, the challenger's superiority becomes twice the previous year's differential. In the fourth year, this figure is three times the size of the base sum, and so on. This yields as an inferiority gradient a straight line which depicts an arithmetic progression in the time-inferiority relationship.

While it is obvious that in a dynamic situation such constancy in the inferiority-gradient trend is highly unlikely, any other premise would unduly complicate analysis.

Exhibit 11-5 is an example of the manner in which Terborgh's technique can be used to compute relative advantages. In this instance a challenger's adverse minimum is being considered in a case where the equipment cost $5,000. An inferiority gradient of $100 a year is postulated, together with a 10 per cent annual interest charge, no capital additions, and no salvage value. Column 1 shows the constant rate of increase in operational inferiority. In the second year of use, this inferiority is only $100; but by the twentieth year the annual differential has increased to $1,900. Column 2 lists the factors for determining the present worths of the operating inferiorities shown in the previous columns. These factors help the decision maker calculate the present value, at the 10 per cent interest rate pertinent to this case, of $1, payable at the end of the year of service indicated. This $1 figure, calculated at the end of the first year of service, has a discounted value at the beginning of that year of only $0.909. Even more notable is the $0.149 calculated as the present worth of $1 of operating inferiority incurred in the twentieth year of service. Column 4 is simply the accumulated present worth of the operating inferiority as of the specific period of service indicated. Thus the $5,541 sum shown for the twentieth year of service is merely the total of the individual figures shown in column 3.

The next column provides capital-recovery factors by means of which uniform annual equivalents, or time-adjusted averages, can be calculated for the respective years. These calculations are shown in column 6. Capital costs, for specific time periods, are listed in column 7. The sum of operating inferiority (column 6) plus the capital costs which would accrue in the specific year (column 7) gives the total time-adjusted cost for the periods indicated. In this instance, the lowest sum is $1,173, incurred in the twelfth year of service. This is the adverse minimum pertinent to the situation.

In those cases involving salvage values and capital additions, numerous other complicating factors are injected. In the interest of simplicity it seems judicious merely to mention these additional variables, which are, however, an integral consideration in most equipment-maintenance-and-replacement cases.

Exhibit 11-5 refers to the derivation of a specific challenger's adverse minimum. Similar calculations must obviously be made for any other likely prospect and also for the defender's adverse minimum. This represents a tedious chore. Consequently, some short-cut devices have

Exhibit 11-5. Derivation of Adverse Minimum of a Challenger Having a Cost of $5,000 and an Inferiority Gradient of $100 a Year, Assuming No Capital Additions and No Salvage Value, with Interest at 10 Per Cent

Year of service	Operating inferiority for year indicated	Present-worth factor for year indicated	Present worth of operating inferiority for year indicated (col. 1 × col. 2)	Present worth of operating inferiority for period ending with year indicated (col. 3 cumulated)	Capital-recovery factor for period ending with year indicated	Time-adjusted annual average for period ending with year indicated		
						Operating inferiority (col. 4 × col. 5)	Capital cost ($5,000 × col. 5)	Both combined (col. 6 + col. 7)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1	$ 0	$.909	$ 0	$ 0	$1.000	$ 0	$5,500	$5,500
2	100	0.826	83	83	0.576	48	2,881	2,929
3	200	0.751	150	233	0.402	94	2,011	2,104
4	300	0.683	205	438	0.315	138	1,577	1,716
5	400	0.621	248	686	0.264	181	1,319	1,500
6	500	0.565	282	968	0.230	222	1,148	1,371
7	600	0.513	308	1,276	0.205	262	1,027	1,289
8	700	0.467	327	1,603	0.187	300	937	1,238
9	800	0.424	339	1,942	0.174	337	868	1,205
10	900	0.386	347	2,289	0.163	373	814	1,186
11	1,000	0.351	351	2,640	0.154	406	770	1,176
12	1,100	0.319	351	2,990	0.147	439	734	1,173
13	1,200	0.290	348	3,338	0.141	470	704	1,174
14	1,300	0.263	342	3,680	0.136	500	679	1,178
15	1,400	0.239	335	4,015	0.131	528	657	1,185
16	1,500	0.218	327	4,342	0.128	555	639	1,194
17	1,600	0.198	317	4,658	0.125	581	623	1,204
18	1,700	0.180	306	4,964	0.122	605	610	1,215
19	1,800	0.164	294	5,258	0.120	629	598	1,226
20	1,900	0.149	283	5,541	0.117	651	587	1,238

SOURCE: George Terborgh, *Dynamic Equipment Policy*, McGraw-Hill Book Company, Inc., New York, 1949, p. 78.

been introduced. The basic assumption of the short-cut approach rests on the demonstrated fact that the difference between the selected adverse minimum and the immediately prior and subsequent periods is generally insignificant. Exhibit 11-5 indicates that, in the illustration in question, the adverse minimum is associated with the twelfth year of service since the adverse minimum of $1,173 is lowest at this point. However, even so slight a variance as plus or minus 2 per cent ($\pm 2\%$) of this figure would encompass the service periods from the ninth year to the seventeenth year. This wide range seems to confirm the conclusion that the rather complex procedure might be superfluous in most instances. The "plateau" in the adverse minimum would seem to warrant a simplification in technique, even though the results might be somewhat less precise.

Terborgh suggests that in a "no-salvage" case a challenger's adverse minimum is dependent entirely upon (1) the acquisition cost, (2) the inferiority gradient, and (3) the rate of interest. Consequently, the following formula can be used to get a satisfactory approximation.

$$\text{Adverse minimum} = \sqrt{2cg} + \frac{ic - g}{2}$$

where c = acquisition cost
g = inferiority gradient
i = interest rate in decimals

Using this formula and the pertinent figures presented in Exhibit 11-5, the short-cut approximation would be computed as follows:

$$\begin{aligned} \text{Adverse minimum} &= \sqrt{2cg} + \frac{ic - g}{2} \\ &= \sqrt{2 \times 5{,}000 \times 100} + \frac{0.10 \times 5{,}000 - 100}{2} \\ &= \sqrt{1{,}000{,}000} + \frac{500 - 100}{2} \\ &= 1{,}000 + 200 \\ &= 1{,}200 \end{aligned}$$

The short-cut computation ($1,200) is very close to the adverse minimum ($1,173) obtained from the lengthier procedure. It would seem reasonable under these circumstances to recommend the less laborious method except in those cases where maximum accuracy is mandatory. While this provision relegates the fundamental technique to a few exceptional situations, it is still imperative for the decision maker to

be acquainted with both methods. The short-cut formula has practical value. The longer, complex procedure illustrates the underlying logic and emphasizes the interrelationship of the pertinent factors.

Up to this point attention has been focused upon deriving the challenger's adverse minimum. It is equally important to calculate the parallel adverse minimum of the defender. In effect, the defender's adverse minimum can be considered to be the net challenger's advantage. The method generally used for this purpose is almost identical with the procedure outlined in technique 1. In this case, however, the difference for each major cost category is viewed as an operating advantage of the appropriate challenger or defender. The following is a simple example of how the short-cut method can be applied with a minimum of calculation.

The grounds-maintenance section of an educational institution currently has four 21-inch Jacobsen Lawn Queen rotary-type gasoline lawn mowers, purchased five years ago at an average cost of $145 each. Present salvage value is estimated at $45 per machine. Each unit is utilized approximately 900 hours per season. Operatives get an average wage of $1.50 per hour. Maintenance costs approximate $20 per mower per year, and fuel expenditures equal $55 per machine.

A proposal has been made to replace the five-year-old equipment with three Kut-Kwick Riding Lawn Mowers with model H-920, 36-inch cut attachments. Each unit would cost about $510. The new mowers presumably would each be used 1,000 hours annually. Operatives would receive a slightly higher pay scale of $1.75 per hour. Maintenance costs would be reduced to $10 per machine, but fuel costs would probably rise to $65 per machine. Total annual savings in floor space for storage purposes would come to about $40. The first step in the analysis is a tabular presentation of next year's operational advantage.

In the following analysis, the direct-labor operating advantage is computed as follows:

Defender's direct-labor cost equals 4 machines times 900 hours each times $1.50 labor cost per hour, or $5,400.

Challenger's direct-labor cost equals 3 machines times 1,000 hours each times $1.75 direct-labor cost per hour, or $5,250. The difference of $150 is a net direct-labor advantage in favor of the challenger.

Similarly, maintenance costs for the present equipment are computed by multiplying 4 × $20 = $80. Subtracting the $30 estimated total maintenance cost, if the new mowers are purchased, leaves $50 as a net maintenance advantage for the challenger. Using the same

procedure, all other pertinent cost differentials can readily be computed. In this instance the challenger is presumed to have a next year's operating advantage of $265.

This figure is the basis for determining the inferiority for both challenger and defender. If $265 is the operating inferiority for the next year, after five years of service for the old equipment, then the gradient, or annual progression, is determined by dividing the $265 sum by 5. Thus $53 is the inferiority gradient, or sum by which the defender's operating inferiority is increased annually. Unless additional information is available, it can generally be assumed that a relatively comparable challenger will have an almost identical inferiority gradient.

Exhibit 11-6

	Next-year operating advantage (differences)	
	Challenger	Defender
Direct labor	$150	
Maintenance	50	
Fuel	25	
Floor space	70	
Taxes and insurance		$30
Total (gross)	$295	$30
Total (net)	$265	

The operating inferiority does not express the total-cost disadvantage of the defender. When capital costs and interest are added, the final figure becomes the defender's adverse minimum. Present worth of the old machines is derived by multiplying the present worth of each machine, $45, by the number of machines. A 10 per cent interest charge on this investment thus equals $18 for the next year. Since each machine decreased in value by $100 over the five-year period, the average annual capital cost for depreciation and obsolescence is $20 per machine, or a total of $80. Adding the defender's operating inferiority ($265) to the defender's next-year capital costs ($18 + $80) yields a defender's adverse minimum of $363.

The challenger's adverse minimum can be estimated by using the short-cut formula. Thus

$$\text{Challenger's adverse min.} = \sqrt{2cg} + \frac{ic - g}{2}$$

$$= \sqrt{2 \times 1{,}530 \times 53} + \frac{0.10 \times 1{,}530 - 53}{2}$$

$$= \sqrt{162{,}180} + \frac{153 - 53}{2}$$

$$= 402.70 + 50$$

$$= \$452.70$$

The conclusion should be obvious. The present equipment, with an adverse minimum of $363, has a distinct advantage over this particular proposal to reequip at a next year's cost of $452.70.

The analysis, however, might be modified by any significant shift in variables. For example, injecting a dollar value for quality of work, speed in performance, or any similar intangible can change the conclusions. Then too, a reduction in the cost of the new equipment or in the interest charges will have an effect upon the decision. For example, a retention of the old wage rate for the operatives of the new equipment would increase the challenger's direct-labor operating advantage from $150 to $900. In turn, this would boost the defender's inferiority gradient, operating inferiority, and adverse minimum to a point where there would be no question as to the economic advantage in favor of the challenger.

While this presentation of the MAPI method is necessarily truncated, it does point out some of the basic requirements of sound equipment-replacement policy. It is a significant departure from old-fashioned rule-of-thumb techniques and even from most conventional bookkeeping notions as to depreciation and obsolescence. The proponents of dynamic equipment policy are themselves among the most serious critics of the proposed method. They caution against any immediate and wholesale application of the procedure until a more definite and explicit pattern of assumptions as to the future can be put forth. They also stress that assumptions such as the premise of a constant rate of inferiority accumulation, while helpful for computational purposes, might be rather unrealistic. The advocates of this newer approach are fully cognizant of numerous other limitations to the more effective determination of a conclusive theory of dynamic equipment replacement. They do believe, however, that despite the limitations and the reliance upon assumptions, sound replacement policy never comes about spontaneously or automatically. Instead, it

is the culmination of a rational, analytical framework by means of which alternatives can be compared. This framework can be constructed and properly maintained only if the proper attitude and a sound and suitable organization are in existence. Even a cursory acquaintance with current replacement policy in many of our industries should suffice to convince us that a significant revamping of management attitude is requisite in this sphere if our economy is to retain its dynamism. The MAPI method, despite its novelty, assumptions, and limitations, seems to be a distinct step in the direction of scientific management and more effective control in industry.

TECHNIQUE 3. Marginal Cost-Revenue Analysis

Both equipment utilization and equipment replacement are closely associated with the concepts of marginal revenue and marginal cost. Marginal revenue is the increment brought about by an additional unit of sales. Marginal cost, in turn, is the extra charge resulting from the production of that additional unit of product. In theory, it is advisable to continue using a specific piece of equipment until the marginal profit (marginal revenue minus marginal cost) reaches a point where better results can be had from the use of some other unit of equipment. This concept can best be explained by a simple illustration.

A machine currently used by a shoe manufacturer to perform the operation of joining the uppers and soles of shoes is being considered for replacement. This equipment is fifteen years old and has been almost entirely "written off" through previous years' depreciation charges. The purchase of new equipment would thus add to capital costs. Processing is done by lots, which in this case have been considered in terms of 100 gross pairs of shoes per lot. A gross, or 144 pairs, is considered as a unit. Present equipment has a practical monthly capacity limit of three lots of 100 gross pairs each, after which point labor costs rise rapidly because of overtime charges and lower productivity. Maintenance costs, likewise, mount disproportionately. The new equipment would be expected to attain an average output of 400 gross pairs of shoes per month before comparable increases in labor and maintenance charges would set in.

After extensive survey work, management believes that the current 300-unit-per-month output is below the sales level which this company could reach if output were increased. The market-research department proposed the list of probabilities shown in column 1 as being highly likely of attainment. Thus, for example, the chances are 98 out of 100 that an output of 200 units per month would easily be absorbed by

the market. On the other hand, if production were stepped up to 700 units per month, the chances that the entire output would be sold are only 50 out of 100.

After reflecting upon these probabilities and upon the marginal costs shown in columns 3 to 7, management reached a decision to abandon the ultraconservative 300-unit-per-month output policy. It was deemed feasible to attempt production at the 600-unit level. As indicated in Exhibit 11-7, the probability that this quantity will be promptly sold is .75.

Exhibit 11-7. Data on Shoe Processing

Probability of sales, Pa, %	Quantity gross pairs, Q	Present equipment: Marginal cost, Unit	Present equipment: Marginal cost, Lot	Total cost	Proposed equipment: Marginal cost, Unit	Proposed equipment: Marginal cost, Lot	Total cost
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
100	100	$ 6.90	$ 690	$ 690	$10.80	$1,080	$1,080
98	200	6.30	630	1,320	4.80	480	1,560
95	300	6.00	600	1,920	3.60	360	1,920
90	400	8.70	870	2,790	5.40	540	2,460
80	500	11.40	1,140	3,930	8.10	810	3,270
75	600	13.50	1,350	5,280	10.50	1,050	4,320
50	700	17.10	1,710	6,990	12.60	1,260	5,580

As an aftermath of this decision to increase output, management had to decide whether to use the present equipment for the entire output, get new equipment, or employ a combination of old and new equipment. Marginal or extra costs for the present and the proposed equipment are listed in Exhibit 11-7. For example, the first lot of 100 units processed on the old equipment would cost $6.90 per unit, or $690 for the entire lot. The second lot of 100 would cost only $6.30 per unit, or $630 for the lot. The combined cost of the two 100-unit lots, as shown in column 5, is $690 plus $630, or $1,320. It should be observed that unit marginal costs are at their lowest for the old equipment at the 300-unit level. Thereafter the cost pattern has a rather precipitous upward swing.

Comparable costs are listed for the proposed equipment in columns 6 to 8. Presumably the relatively high unit marginal cost at the lowest production rate results from the burden of high fixed charges being allocated over a small quantity of product. It can readily be inferred from the basic data that if output were held at 300 units, there would

be no difference between present and proposed methods. At the higher rates of output the new equipment has a distinct advantage. Exhibit 11-8 provides an easy graphic means for comparing the several alternatives. The top horizontal column and the first vertical column refer to the rate of output for the proposed and the present equipment, respectively. The figures in the squares show the total cost for production at the different output levels and for all possible alternatives of equipment utilization. For example, a rate of output of 100 units on the new equipment would cost $1,080. On the old equipment this same performance would cost only $690. The 200-unit level has three alternative methods of production. Produced entirely on the new equipment, total costs would amount to $1,560. The old method would cost $1,320. Use of both sets of equipment to produce 100 units each would result in a combined cost of $690 plus $1,080, or $1,770. Following this method of reasoning, it is evident that the optimum combination, under current circumstances, for an output of 600 units should consist of 400 units from the new equipment and 200 units from the old machine. In fact, up to and including the 700-unit level, it would be advisable to maximize the use of the new equipment up to the 400-unit output level and to assign the residual production up to 300 units to the old equipment. The old machine would thus serve as a stand-by facility for the intermediate production range of 401 to 700 units.

Up to this point the entire analysis has been based upon a marginal-cost consideration. If, for example, the product had a selling price of $7.80 per unit, it would be a relatively simple matter to compute both marginal revenue and total revenue. Subtracting the related costs from revenue would yield the gross profit. At the 600-unit level revenue would total $600 \times \$7.80 = \$4,680$. The lowest cost combination, as shown in Exhibit 11-8, is $3,780. Thus gross profit equals $900. This profit margin is attainable, however, only if there is a demand for all 600 units of product. Since the probability that this quantity will be sold is only .75, there is 1 chance in 4 that the gross profit of $900 will not be attained. The decision maker must now determine, in addition to the maximum gross-monthly-profit potential of $900, a comparable minimum gross-profit potential, keeping in mind all the premises that have been accepted up to this point. The derivation of this sum requires some relatively complex algebraic computations involving the probabilities that the specific quantities will be sold, together with additional costs accruing from unsold quantities. A rather rough approximation of the "probability" adjusted gross-profit estimate can be obtained by multiplying the maximum gross

Exhibit 11-8

Proposed / Present	000	100	200	300	400	500	600	700
000		1080	1560	1920	2460	3270	4320	5580
100	690	1770	2250	2610	3150	3960	5010	
200	1320	2400	2880	3240	3780	4590		
300	1920	3000	3480	3840	4380			
400	2790	3870	4350	4710				
500	3930	5010	5490					
600	5280	6360						
700	6990							

profit times its probability of attainment. This set of figures is shown in column 6 of Exhibit 11-9. It is apparent from this set of figures that profit potential is maximized at the 600-unit level. Increasing output to 700 units results in a decline from $675 to $540 in the adjusted probable income. This decline is the consequence of the significantly diminished probability that all 700 units will be profitably moved into the market. Obsolescence, extra storage charges, and extra investment costs will tend to outweigh profit as greater quantities of the product move sluggishly into the market. It has been emphasized

Exhibit 11-9

Probability of sale, Pa, % (1)	Quantity gross units, Q (2)	Total revenue, R (3)	Total cost, C (4)	Gross income, I (5)	Adjusted probable income, Pa × I (6)
100	100	$ 780	$ 690	$ 90	$ 90
98	200	1,560	1,320	240	235
95	300	2,340	1,920	420	399
90	400	3,120	2,460	660	594
80	500	3,900	3,150	750	600
75	600	4,680	3,780	900	675
50	700	5,460	4,380	1,080	540

that this adjusted gross profit based on probable sales potential is a rather rough approximation. A more accurate statistical appraisal could be ventured if it were deemed feasible. Nevertheless, with even this approximation, the decision maker is now better prepared to conclude the analysis. Obviously, in this instance the new equipment should be purchased. The present equipment should be kept in operating condition. If demand falls to 200 units or less, the old equipment should be used. If demand ranges between 200 and 400 units, the new equipment should be put to use and the old machine should be idled. With demand in the 400- to 700-unit range, both pieces of equipment should be operated, with the old machine performing in a residual capacity.

The recent emphasis on operations research, linear programming, and quantification in decision making has given considerable acceptance to this type of analysis. Despite exaggerated claims by some would-be operations-research experts, it must be realized that economists have for quite some time stressed the importance of marginal-profit analysis in the sphere of managerial decision making. The current stress on the use of scientific analytical techniques for top-level decision making is less of an innovation and more an intensified application of long-available techniques than most managers realize. This is not meant to be a disparaging comment on operations research and similar aids to modern management. There is a real need for even a much greater stress on system and science in the more effective control and use of organizations.

As a note of caution, it must be kept in mind that while the latter portions of this type of analysis are basically arithmetic and hence yield conclusions that appear to be indisputable, the entire sequence rests upon a number of premises that can be questioned. Estimates of both marginal revenue and marginal costs are subject to numerous internal and external forces which can easily modify the calculations. Revenue is always subject to the vagaries of the market place. Costs depend upon a multitude of volatile factors. Even more questionable are the estimates of probabilities as to sales potential. Despite the most perfect statistical treatment in their derivation, these figures can be changed radically by any sudden shift in pertinent parameters. While this caution should constantly be kept in mind, there is no implication that the technique yields useless data. On the contrary, even with its limitations, it permits logical analysis of equipment-utilization-and-replacement situations where too frequently decisions are made on the basis of expediency and hunch.

ILLUSTRATION 1. Cincinnati Milling and Grinding Machines Company Replacement Analysis Manual

The objective appraisal of equipment replacement as presented in the MAPI method is somewhat complex for many would-be practitioners of sound equipment-replacement policy. While recognizing the merit of the concepts highlighted in the MAPI method, most decision makers in this sphere stress the need for a less complex and

Exhibit 11-10. Explanation of Terms Used in Work Sheet

EXPLANATION OF TERMS USED IN WORK SHEET*

1. **DIRECT LABOR**—Measure production time in terms of operator wages and include any incentive premiums and bonuses for next year. Consider any combination or elimination of operations, either for processing reasons or improved quality reasons, and any increase in production.

2. **INDIRECT LABOR**—Cost of shop administrative, supervisory, inspection, helper, and janitorial labor.

3. **FRINGE BENEFITS**—Cost of vacation pay, premium, bonus, pensions, Social Security, group insurance, medical service, profit-sharing and other company paid benefits.

4. **MAINTENANCE**—Cost of ordinary operation maintenance, but not extensive repairs or rebuilding.

5. **TOOLING**—Cost of jigs and fixtures, cutters, cutting tools, grinding wheels, attachments, and other tooling costs.

6. **SCRAP**—Cost of work spoilage on both New and Old Equipment due to equipment inadequacies.

7. **PROPERTY TAXES AND INSURANCE**—Enter costs for both Old and New Equipment.

8. **DOWN TIME**—Value of time lost due to breakdowns, repairs, and adjustments.

9. **FLOOR SPACE**—Consider the value of floor space for Old and New Equipment.

10. **OTHER COSTS**—Any other factor which may account for a significant cost such as Power, fuel gas, compressed air supplies, lubricants, coolants, belts, special oils, storage of materials, etc.

11. **TOTAL OPERATING COSTS (NEXT YEAR)**—Sum of lines 1 through 10 listed under OLD and NEW equipment.

12. **NET OPERATING COST FAVORING NEW EQUIPMENT**—Total Operating Cost (Next Year) of NEW equipment subtracted from Total Operating Cost (Next Year) of OLD equipment.

13. **DISPOSAL VALUE (NOW)**—Current used equipment market value.

14. **DISPOSAL VALUE (NEXT YEAR)**—Estimated used equipment market value one year from now.

15. **LOSS OF DISPOSAL VALUE (NEXT YEAR)**—Line 14 subtracted from Line 13.

16. **INTEREST ON DISPOSAL VALUE**—If the Old Equipment were sold, the money could be used as operating capital. As such, it would earn a return. Enter as percentage value (see explanation 23). Multiply Disposal Value (line 13) by percentage value (line 16). This is dollar value for line 16.

17. **OLD EQUIPMENT CAPITAL COST (NEXT YEAR)**—Sum of lines 15 and 16. If Old Equipment is kept in service, the amount shown here represents a loss of available capital for next year. In this Analysis, this amount is considered a Capital Cost. It is a charge against keeping the Old Equipment in service.

18. **ESTIMATED PRIMARY SERVICE LIFE**—Estimated length of time New Equipment can profitably be used on this application. (Useful life for other purposes may be longer).

19. **REQUIRED INVESTMENT**—Total equipment cost plus shipping and installation charges.

20. **ESTIMATED DISPOSAL VALUE**—Estimated used equipment market value of New Equipment at the end of its primary service life.

21. **DISPOSAL RATIO**—Estimated Disposal Value of New Equipment (line 20) divided by Required Investment (line 19), and express as a percent. Necessary for Depreciation Chart computation (line 22).

22. **DEPRECIATION CHART VALUE**—This chart portrays depreciation or loss in value due to deterioration and obsolescence. Prorated over the estimated primary service life, the chart indicates by percent of original cost the first year loss chargeable to these factors. It is considered a Capital Cost. Instructions for obtaining proper percentage value are included with the Chart on page 4. Enter this percentage value on line 22. Multiply item Y, line 19 by percentage value, line 22. This is dollar value for line 22.

23. **INTEREST ON REQUIRED INVESTMENT**—Purchasing the New Equipment will tie up a sum of money (Required Investment, line 19) for a considerable period of time. If invested or used as operating capital, this money would yield interest or income to the company. Therefore, select an interest rate which is the same or close to the current rate your company is earning on its operating capital. Multiply Required Investment (Y, line 19) by this percentage value (D, line 23). This is dollar value for line 23.

24. **NEW EQUIPMENT CAPITAL COST (NEXT YEAR)**—Sum of lines 22 and 23. This is the Capital Cost of the New Equipment for the first year.

25. **NET CAPITAL COST FAVORING OLD EQUIPMENT**—Total Old Equipment Capital Cost (Next Year) line 17, subtracted from Total New Equipment Capital Cost (Next Year) line 24.

26. **SAVINGS FROM REPLACEMENT NEXT YEAR (PENALTY OF NON-REPLACEMENT)**—Net Capital Cost FAVORING Old Equipment (line 25) subtracted from Net Operating Cost FAVORING New Equipment (line 12). A plus value indicates replacement should be made and the greater the amount, the greater the urgency. A negative value indicates replacement is premature at this time.

*See REPLACEMENT ANALYSIS MANUAL for a more complete discussion of these terms.

more readily usable tool. Consequently, numerous simplified versions of equipment-economy study have been introduced in recent years. An excellent example is that presented in the Cincinnati Milling and Grinding Machines Company's *Replacement Analysis Manual.* The basic elements of this technique are shown in the following reproductions. Exhibit 11-10 describes the 26 items which are essential to the replacement analysis. These 26 items are set forth in tabular form in Exhibit 11-11, which is, in effect, the work sheet for calculating

Exhibit 11-11. Replacement Analysis Work Sheet

REPLACEMENT ANALYSIS

Work Sheet

OLD EQUIPMENT		NEW EQUIPMENT	
Manufacturer	Other Makes	Manufacturer	Cincinnati Milling Machine Co.
Type and Size	2 - Milling Machines	Type and Size	No. 2-72 Auto. Rise & Fall
Machine No.	2311 and 2495	Model No.	OM Miller
Year Built	1936 and 1940	Estimate No.	Chicago-5754
Department	Lathe Department	Date of Proposal	8-19-53

OPERATING COST ANALYSIS
(Next Year Only)

COST ITEMS	OLD	NEW
(1) Direct Labor (Space for calculations Page 4)	$ 15900.00	$ 11176.00
(2) Indirect Labor		
(3) Fringe Benefits		
(4) Maintenance	1020.00	21.00
(5) Tooling		
(6) Scrap	760.00	333.00
(7) Property Taxes and Insurance (1% of Cost)	71.00	208.00
(8) Down Time	1390.00	
(9) Floor Space		
(10) Other Costs (Power)	123.00	246.00
(11) Total Operating Costs (Next Year)	$ 19284.00 (A)	$ 11984.00 (B)

(12) NET Operating Cost FAVORING NEW Equipment .... (A minus B) .... $ 7300.00

CAPITAL COST ANALYSIS
(Next Year Only)

OLD EQUIPMENT			NEW EQUIPMENT		
(13) Disposal Value (Now)	$ 850.00		(18) Estimated Primary Service Life	15 yrs.	
(14) Disposal Value (Next Year)	$ 750.00		(19) Required Investment (Y)	$20785.00	
(15) Loss of Disposal Value (Next Year)		$ 100.00	(20) Estimated Disposal Value (X)	$ 2000.00	
(16) Interest on Disposal Value 10 % (of Line 13)		$ 85.00	(21) Disposal Ratio (X÷Y)	9.7 %	
Rebuilding Costs	$4000.00		(22) Depreciation Chart Value (C)	8.8 %	(Y×C) $ 1829.08
Extended Life	5 Yrs.				
Proration of Cost		$ 800.00	(23) Interest on Required Investment (D)	10 %	(Y×D) $ 2078.50
Interest on Rebuilding	10%	$ 400.00			
(17) Total Old Equipment Capital Cost (Next Year)		$1385.00	(24) Total New Equipment Capital Cost (Next Year)		$ 3907.58

(25) NET Capital Cost FAVORING OLD Equipment .... (Line 24 minus Line 17) .... $ 2522.58

(26) SAVINGS FROM REPLACEMENT NEXT YEAR .... (Line 12 minus Line 25) .... Plus $ 4777.42

Page 3

the gross and the net costs for the alternative units of equipment. This work sheet is actually divided into two distinct parts: the operating-cost analysis and the capital-cost analysis.

Each of the first 10 items listed in the operating-cost analysis refers to the respective operating cost for both the old and the new equipment. Item 11 is the total of the preceding 10 cost categories. Item 12 indicates the net operating cost favoring the new equipment. This net advantage of the new equipment is, in a sense, hypothetical, since the essence of technological change is industrial advancement through better equipment, better quality, and lower operating costs.

Items 13 to 24 pertain to the calculation of capital costs for both units of equipment. Next year's total capital cost for the old equipment is shown as item 17, while the comparable new-equipment capital cost is summarized in item 24. The difference, item 24 minus item 17, is the net capital cost favoring the old equipment. Again, this particular advantage of the old equipment over the new equipment is practically a postulate. At this point it should be evident that the first half of the work-sheet analysis consists in the determination of the new equipment's cost advantages while the second half of the work-sheet analysis yields the old equipment's net cost advantage. The last line, item 26, simply shows the savings, and in some cases the losses, accruing from the replacement. All costs in this analysis are estimates based on next year's performance.

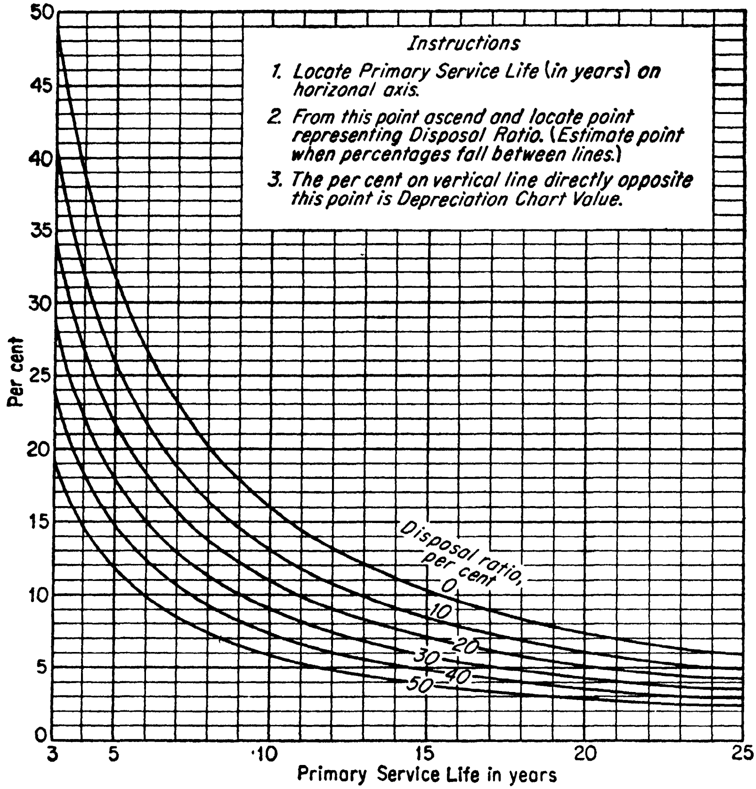
The numerical values used in Exhibit 11-11 refer to an actual case history recorded by Cincinnati Milling and Grinding Machines Company. The net operating advantage of $4,777 in favor of the new equipment is primarily the result of less direct labor needed, lower maintenance charges, reduced scrappage of materials, and elimination of down time.

In the capital-cost analysis, it is important to note that the old equipment's book value, even though determined by the soundest accounting techniques, is not considered. Instead, the calculations are based on the disposal value. While this might be disconcerting from an accounting point of view, stress on disposal value rather than book value is based on realism. Nevertheless, there is bound to be some reluctance on the part of management to dispose of an asset if there is a significant negative difference between book value and disposal value. This reluctance would be intensified if the savings from replacement, as shown on line 26, were equal to only a small portion of the investment required for the replacement.

Exhibit 11-12 provides a rather helpful tool for rapid calculation of depreciation value. Two variables, the primary service life in years

and the disposal ratio as a percentage, must be known. The primary service life is measured on the horizontal scale, while the curved lines on the chart refer to the disposal value. Reading across to the vertical scale provides, in percentage form, an approximation of the depreciation value for a piece of equipment after a given number of

Exhibit 11-12. Chart for Determining Depreciation Value



SOURCE: Cincinnati Milling and Grinding Machines, Inc., Cincinnati, Ohio, and Machinery and Allied Products Institute, Washington, D. C.

years' usage. As an illustration, the data in Exhibit 11-11 (line 21) indicate a disposal ratio of 9.7 per cent for the No. 2–72 automatic-rise-and-fall miller. Thus after 3 years the depreciation value is estimated at about 40 per cent of capital cost. After 10 years this value has declined to 13 per cent of capital cost. These calculations, once again, are obtained by noting the years on the horizontal scale, measuring upward to, in this instance, the 10 per cent disposal ratio and finally checking the corresponding value on the vertical scale. Where

the disposal ratio is other than one of the six figures shown on the chart, judicious estimates can readily be made to locate the appropriate disposal-ratio curve.

QUESTIONS

1. Upon what depreciation method does Exhibit 11–12 seem to be based?
2. Approximately what is the capital-recovery period?
3. Show arithmetically how quantitative and qualitative differentials might affect the decision in this case.
4. Using the data shown in Exhibit 11–11 and postulating all other necessary information, show how an analysis would be made by (*a*) the MAPI method; (*b*) the marginal cost-revenue method.

ILLUSTRATION 2. The Hypo Steel Company[4]

Several years ago *Business Week,* in one of its special industry studies, presented a very interesting case analysis showing the effects of depreciation policy upon corporate performance. Members of the *Business Week* staff created a hypothetical company, Hypo Steel, by averaging financial and operating data published by the nine largest steel-producing corporations. Exhibit 11-13 condenses these pertinent financial and operating data as of the end of 1955.

Typical of all manufacturing industry in a dynamic economy, Hypo Steel must determine if it is to expand productive facilities. Assuming an affirmative answer, Hypo must then decide upon the degree of expansion, the type of new facilities, location, financing, and all other related matters. In this case, the pattern was set by the only completely new steel mill constructed in more than twenty years—U.S. Steel's Fairless Works, a 2.2-million-ton integrated mill. The present ingot capacity of the hypothetical company was calculated as being only slightly over 11 million tons. Thus a 2-million-ton expansion might seem somewhat out of proportion. Nevertheless, the proposal to build new facilities was postulated upon the conviction that a 2-million-ton, completely integrated mill was essential from an economic point of view. Analysis also showed that because of various impediments to maximum utilization of capacity, the new facilities would be operated at an average of only about 70 per cent of potential. Thus the extra output from the new mill would approximate 1.4 million ingot tons. At an average selling price of $144.50 per ton, the additional gross revenue would total $202.3 million.

The new capacity would cost the company $250 per ingot ton for construction purposes together with an additional 10 per cent of this

[4] Adapted from "Fast Write-off Holds the Key," *Business Week,* Oct. 13, 1956, pp. 86–100.

Exhibit 11-13

FINANCIAL POSITION AT END OF 1955

		Millions of dollars
Working capital		$337.7
Investments and long-term receivables		36.1
Plants and equipment.		
Gross cost	$1,129.0	
Depreciation reserve	637.5	
Net		491.5
All other assets		5.8
Total assets		$871.1
Less:		
Long-term debt		124.2
Reserves		29.6
Shareholders' investment		$717.3
Represented by:		
Preferred stock (576,420 shs.)	$ 57.6	
Common stock (12,626,000 shs.)	201.5	
Income retained in the business	458.2	
Ingot capacity—11,097,000 N.T.		

OPERATING RESULTS FOR 1955

		Millions of dollars
Sales and operating revenues		$1,211.1
Income from operations		$ 275.4
Less:		
Amortization, depreciation, and depletion		69.6
Interest charges		3.8
Federal income taxes		100.8
Net income		$ 101.2
Less dividends:		
Preferred		3.9
Common		36.7
Retained in the business		$ 60.6
Cash throwoff:		
Net income		$ 101.2
Amortization, depreciation, and depletion		69.6
Total cash throwoff		$ 170.8
Net income per share of common	$ 7.70	
Market value per share	$75.21	
Dividends per share—common	$ 2.91	
Yield	3.9%	
Price times earnings	$ 9.8	

SOURCE: *Business Week,* Oct. 13, 1956, p. 87.

figure, or $25 per ingot ton for working capital. Total cost for the new installation is estimated at $500 million plus $50 million for working capital. The additional income from operations attributable to the new capacity is estimated at $45.6 million. This figure is based upon current cost patterns, including the conventional 25-year amortization of capital equipment.

Hypo's policy makers must determine whether the 25-year amortization is preferable to the double-declining-balance amortization method which is also permissible under current tax rulings. Another alternative, petitioning for a certificate of necessity and writing off the cost of the new facilities in 5 years, is also to be considered. The results of these three amortization plans are shown in Exhibit 11-14. It would seem that on the basis of net income, the conventional 25-year-amortization method, yielding net income of $3.7 million, is preferable. However, when the cash throwoff is computed, after adjustments

Exhibit 11-14. Results of Hypo Steel Company's New Mill—Amortized Three Different Ways

	With 25-year amortization	With declining-balance amortization	With 5-year amortization
		Millions of dollars	
Income from operations	$ 45.6	$ 45.6	$ 45.6
Less:			
Amortization (5-year average)	20.0	34.1	82.5
Interest at 3½% (average)	17.8	17.3	16.0
Income tax	4.1	—	—
Net income	3.7	−5.8	−52.9
These losses can be offset against Hypo's other earnings. So:			
Cash throwoff:			
Net income	3.7	—	—
Amortization	20.0	34.1	82.5
Tax saving	—	3.0	27.5
Less net loss	—	−5.8	−52.9
Total throwoff per year	$ 23.7	$ 31.3	$ 57.1
If the entire cash throwoff is used to reduce debt Hypo will have:			
Debt at end of 5 years	$431.5	$393.5	$264.5

SOURCE: *Business Week*, Oct. 13, 1956, p. 87.

are made for amortization plus tax savings resulting from the net losses, as determined by the last two methods, the decision makers should probably modify their recommendations. Cash throwoff refers to the amount of money that the company can keep out of its current earnings. The significant difference in the annual cash throwoff is brought about entirely by the differences in depreciation policies. Even though the certificate of necessity would permit the accelerated writing off of only about 75 per cent of the investment, one-fifth of the $375 million thus affected would mean a depreciation allowance of $75 million. To this should be added the amortization, computed in this case by the double-declining method, of $7.5 on the remaining $125 million of cost not covered by the certificate of necessity.

Another aspect, the tax saving resulting from the loss on the new mill's operation, must also be considered. Of course, this feature is important only as long as there is a profit resulting from the other

company activities. It should also be kept in mind that, presumably after the 5-year period of fast write-off, when the new assets have been amortized for the most part, profits as shown on the books should increase significantly.

While in this case the fast write-off shows huge losses in the first 5 years, it should be remembered that these losses are fundamentally bookkeeping figments. Actually, the amortization provides funds which remain with the company and can be used for a great variety of purposes. Thus the financial position of the concern is greatly improved. This characteristic is clarified in the last two lines of Exhibit 11-14. The annual cash throwoff under the 5-year-amortization plan amounts to $57.1 million as compared with only $23.7 million under the conventional 25-year-amortization practice. If the entire cash throwoff is applied to reducing the increased debt, resulting from the financing of the new facilities, the company will owe only $264.5 million at the end of 5 years. The $431.5 million and $393.5 million figures applicable to the first two techniques clearly show the relative advantage of the fast-write-off philosophy.

In its very interesting article *Business Week* then proceeds to explain how the decision which the Hypo Steel policy makers must formulate has long-run ramifications, not only for the individual concern but for the over-all economy. It is understandable that a single company can never set the pace for all industry. Yet practices and policies are first initiated by one or a few companies. Once their merits have been demonstrated and acceptance becomes widespread, performance at the national level is invariably affected. Assuming this premise, it should be evident that Hypo Steel's resolution of its amortization problem can ultimately have much more extensive consequences.

QUESTIONS

1. Show arithmetically how fast write-off might have subsequent negative effects upon profits.
2. Would fast write-off have more meaning for general-purpose- than for special-purpose-equipment amortization?
3. What effect would you expect the fast-write-off policy to have upon the market value per share of Hypo's common stock?
4. Would legalizing a more widespread usage of fast write-off have any consequences upon the machine-tool industry?
5. Why is a loss incurred by one component of a company frequently so important for long-run corporate-profit calculations?

ILLUSTRATION 3. ***Financing Reequipment***

The B. F. Goodrich Company, in a letter to its employees, demonstrated very clearly the inadequacy of current Federal legislation perti-

nent to industrial-depreciation policy. The letter points out that, in a specific instance, a standard piece of equipment in rubber processing, a three-roll calender, cost $23,375 when purchased in 1927. Straight-line depreciation, applicable to this case, resulted in the recovery of the original capital investment in equal annual installments over a period of twenty years. Thus theoretically, when it came time to replace the calender in 1957, a sum of $23,375 was available in the depreciation reserve. However, when replacement was ventured, it was discovered that a comparable new calendering machine would now cost $140,000.

The B. F. Goodrich letter then proceeds to ask where the additional $116,625 is to be obtained. The logical answer would seem to call for tapping the earned-surplus account, namely, the fund of earnings belonging to the stockholders but retained by the corporation. This account, however, since it is comprised of corporate earnings, is subject to Federal taxes. The Company must pay 52 cents out of each dollar earned to the Federal government for income-tax purposes. Thus B. F. Goodrich must earn an income of $242,970 before taxes in order to accumulate the $140,000 needed to pay for the new equipment.

The letter then stresses an often overlooked yet extremely vital consideration. The additional income can come only from additional sales, in this case to the extent of about $2 million worth of products.

A further complicating factor is injected by qualitative differentials. If Goodrich is to remain competitive with the other leaders in the rubber industry, then it becomes imperative that the old-type three-roll calender be replaced with the technologically superior three-roll "cross-axis" calender. This superior piece of machinery would cost $238,000 instead of the $140,000 price of the former. The disparity between the sum needed to finance equipment replacement and the actual sum available from present depreciation policies is most obvious. If the superior unit of equipment is to be purchased, nearly $3½ million more product must be sold to earn enough to meet the purchase price.

This particular problem is certainly not restricted either to B. F. Goodrich or the rubber industry. It is a chronic complaint in practically every segment of business that technological advances, spiraling labor costs, governmental tax policies, and inflationary distortions seriously hinder the desires and efforts of American industry to equip itself with the newest and best available means of production.

QUESTIONS

1. What measures should be taken to alleviate this apparent deterrent to more intensified mechanization?
2. Would a more universal application of the MAPI method help ease the situation?

3. What factors might serve to mitigate or neutralize this industry complaint?

4. Is this imperfection basically an accounting problem?

5. Assume that in a given year total equipment to be replaced has an original value of $1 million. What would be the comparable extra net income and extra gross sales necessary if technological and tax factors prevailed comparable with those described at B. F. Goodrich?

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CHAPTER 12

Methods Analysis

DEFINITION AND DESCRIPTION

The production techniques described in this chapter are known by a variety of names such as motion study, work measurement, methods design, work simplification, and methods analysis. In every instance, regardless of the variance in names, the purpose of this type of industrial management technique is to determine the optimum motions and their sequences in the performance of prescribed tasks. Methods analysis thus strives to eliminate waste resulting from meaningless, misguided, or inefficient motions in the application of human energy to the fulfillment of useful industrial activities. Despite the lack of a uniform nomenclature and the great variance in techniques, there is a unifying bond since all these methods are concerned with the manner in which industrial activities can best be performed. In every one of these techniques the objective is to get a better way of doing the job through: (1) elimination of superfluous motions, (2) combination of related activities whenever feasible, (3) modification of activity sequences, and (4) simplification of activity cycles.

There is no need for profound speculation to make the inference that practically every industrial operation can be carried out in a variety of ways. Generally, custom, economic considerations, and technological factors dictate the selection of a specific work pattern. Despite the influence of these forces, however, performance is seldom anywhere near either the attainable optimum or the absolute maximum levels.

Determination of the maximum potential and the means by which this maximum might be approximated is actually the basic function of methods analysis. While in every instance maximum utilization of resources and maximum attainment are ultimate objectives, realism dictates modification of aspirations. Thus, for all practical purposes, the maximum is tempered and the attainable optimum becomes the immediate goal. This optimum might be translated into the universally well-known phrase the "one best way." Common sense tells us that even the "one best way" is relative, depending upon a great complex of inherent and external forces.

The "one best way" might be selected (1) arbitrarily, (2) by custom, (3) because of expediency, or (4) through a deliberate and objective scientific appraisal. One of the cardinal precepts of this text is the premise that all managerial decisions, including those pertinent to choice of operating methods, should be made by scientific procedures. Consequently, there is no need to elaborate upon the superiority of the scientific techniques described in this text as compared with rule-of-thumb methods.

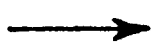
Industry has always recognized that some production methods are better than others. Quality items, for example, focus attention upon skill. In turn, this implies that the skilled individual has found a way to do the job in a fashion superior to the work pattern of the less skilled. This emphasis upon skill, however, does not mean that the work habits of the most skilled can always be duplicated and be applied in the typical industrial situation. Acquisition and application of skill might entail excessive time and prohibitive costs. The skill requirements might be such that only a very small portion of the work force could ever acquire requisite qualifications. These and similar reservations as to the feasibility of using individual skill as the "one best way" yardstick lead to the substitution of scientifically deduced norms in place of the more obvious individual paragons of skill. The fundamentals of scientific methodology have been emphasized in Part One and particularly in Chapter 2. It should be noted that proper methods analysis in every instance requires a body of pertinent facts, the breaking down of jobs and tasks into elements, the careful study of these elements, and finally, the regrouping of the elements into the most efficient combinations.

Frederick Taylor's classic experiments, previously described, amply illustrate the logic and the procedure associated with acceptable methods analysis. The basic difference between Taylor's approach and the efforts of earlier proponents of improved industrial methods was the greater stress placed by Taylor upon minute and seemingly ir-

relevant details. Every aspect of a job, including even the seemingly incidental items, was carefully scrutinized. Every possible alternative was considered. Every combination of factors and elements, regardless of how fantastic it might have seemed initially, was studied. The alternative showing the best results for the least cost and effort could then be chosen on an objective basis. This alternative might be designated as the "one best way" until a more favorable combination could be effected.

The scientific-management pioneers realized at an early date in the evolution of this new concept that in many industrial jobs there were practically an infinite number of methods modifications. They also assumed that certain motion combinations were more fruitful than others. This led to the introduction of standards for elemental motions. The best-known contribution in this sphere is the now universally ac-

Exhibit 12-1. Therblig Symbols and Colors

THERBLIGS					
Symbol	Name	Color	Symbol	Name	Color
	*Search*	*Black*		*Inspect*	*Burnt ochre*
	*Find*	*Grey*		*Pre-position*	*Sky blue*
	*Select*	*Light grey*		*Release load*	*Carmine red*
	*Grasp*	*Lake red*		*Transport empty*	*Olive green*
	*Transport loaded*	*Green*		*Hold*	*Gold ochre*
	*Position*	*Blue*		*Rest for overcoming fatigue*	*Orange*
	*Assemble*	*Violet*		*Unavoidable delay*	*Yellow ochre*
	*Use*	*Purple*		*Avoidable delay*	*Lemon yellow*
	*Disassemble*	*Light violet*		*Plan*	*Brown*

SOURCE: A. E. Shaw, "Motion Study," in H. B. Maynard (ed.), *Industrial Engineering Handbook,* McGraw-Hill Book Company, Inc., New York, 1956, pp. 2–63.

cepted *therblig*. This term, incidentally, was derived by slightly modifying the surname of its originator, Frank Gilbreth, spelled backward. By definition, a therblig is a basic element of motion or of accomplishment representing such actions as grasping, holding, etc. The 18 original therbligs are shown in Exhibit 12-1. Subsequent modifications have increased the number of therbligs so that current listings include 22 or more. Easily identifiable symbols, as shown in the chart, are associated with specific therbligs. These symbols presumably facilitate charting a work sequence and aid in the subsequent analysis. Special colors are also sometimes used with the same purpose in mind.

A simple operation, such as signing a letter, might be broken down into the sequence as given in Exhibit 12-2.

Exhibit 12-2

	Therblig		
	Symbol	Letter	Color
1. Look for letter		Sh.	Black
2. Find letter		F.	Gray
3. Grasp letter	∩	G.	Lake red
4. Position letter to desk	9	T.L.	Green
5. Reach for pen	→	Sh.	Black
6. Grasp pen	∩	G.	Lake red
7. Transport pen to letter		T.L.	Green
8. Sign letter	U	U.	Purple
9. Return pen to holder Etc.		T.L.	Green

This sequence can obviously be modified, depending upon important circumstances. In any case, the reduction of a task to its basic components permits objective analysis. Careful study will usually reveal superfluous motions. Then too, comparison of one operating sequence with likely alternatives should help determine the preferable method. Very frequently choosing one sequence of operations in preference to another can only be done when other factors, such as time and cost, are injected. However, since these aspects will be studied in the next chapter, their significance will not be elaborated upon at this point.

Principles of Motion Economy. The experiments of the Gilbreths led to the formulation of a set of principles which, after modification, have become almost universally accepted. These principles, sometimes referred to as laws, can logically be divided into (1) those primarily concerned with the person, (2) those referring to the work place, and (3) those related to supplemental items. The following list, while not complete, presents the more important of these principles of motion economy.

1. For more efficient movements of the body:
   a. Motions should be kept to the lowest possible order. For example, finger motions are definitely less exerting than arm motions.
   b. Rhythm and automaticity should be built into the sequence of motions.
   c. Continuous "curved" motions are preferable to those with straight-line patterns, particularly when the latter involve sudden and drastic changes in course.
   d. When using both arms, motions should be made simultaneously, in a symmetrical fashion and preferably in opposite directions.
   e. Both hands should begin and end their respective activity cycles at the same time.
   f. Whenever mechanically possible, hands and arms should be relieved of work that can be performed by the feet or other parts of the body.
2. For more efficient use of the work place:
   a. Fixed stations and prepositioning should be utilized for all tools and materials.
   b. Whenever feasible materials should be moved mechanically as by gravity feed and "drop delivery."
   c. The work area should approximate the normal grasp area as regards reaching distance and height of work place.
3. For more efficient motion sequences:
   a. Therbligs should be counted and studied. The best sequence usually entails the least number of therbligs for that task.
   b. All delays should be analyzed with a view to curtailment and ultimate elimination.
   c. All variations must be studied to find the best sequence and the shortest time.

These 12 principles can, obviously, be expanded to include many other important facets of motion economy. The items listed are merely the more apparent and the more universally accepted. As with all

precepts, the effectiveness of these principles lies more in the spirit with which they are applied than in the thoroughness with which they are described and enumerated.

As a note of caution to the overzealous proponent of the "one best way," it must be emphasized that motion economy does not mean parsimony or niggardliness. Too severe a pruning of motions can impair the effectiveness of the activity cycle. A judicious reduction, particularly of extraneous motions, must always be consistent with the basic objective, that is, the best performance of a given task.

In his authoritative text Dr. Gerald Nadler[1] stresses the four fundamental factors invariably instrumental in the selection of a specific methods design. These factors are:

1. Economic
2. Hazard
3. Control
4. Psychological

Explaining in detail each of these factors, Dr. Nadler stresses that cost considerations are invariably paramount. A compilation of the numerous cost-incurring variables is absolutely necessary so that total cost for each feasible alternative could be computed. As a balance to this cost incurring, each item should also be scrutinized to ascertain its contribution in terms of cost saving. Indecision frequently results from the speculative character of some of the cost-savings aspects. In such cases judicious estimates must be made.

The hazard factor is particularly important in this age when the worth of a man in terms of sociological and psychological values likewise inflates the "economic value" of the individual. For example, insurance costs tend to penalize the concern which has higher-than-average accident frequency and severity experience. Then too, the steadily increasing cost of equipment means that overhead costs mount whenever capacity is idle because of accidents. Far more important is the steadily increasing public intolerance of any enterprise which permits unnecessary work hazards. This importance of the hazard factor can prevent installation of a "better" method, or on the other hand, it might accelerate the shift from one to another operating procedure.

The control factor relates to the degree to which the specific-methods pattern has built into it safeguards for quantity and quality control purposes. This feature will undoubtedly become more and more important as industrial mechanization evolves into what is commonly

[1] *Motion and Time Study,* McGraw-Hill Book Company, Inc., New York, 1955, p. 221.

referred to as automation. As technological restrictions are placed upon the production process, significant limitations are imposed upon the specific operations to be performed, their time allowances, and their sequence.

Psychological factors undoubtedly play an important role in the selection of a given work pattern. Custom, for example, does not always yield readily to an innovation simply because the new method's proponents praise its merits. Work habits, like all habits, tend to be deeply rooted and resistant to change. These psychological factors are particularly perplexing when vital technological improvements are hindered because the workers view the new methods suspiciously as a job-elimination device.

These four factors are obviously only a few of the forces affecting the continued use and the modification of work methods. Highlighting these factors should help one better to appreciate the complexities entailed in most changes in work methods. It is the rare exception when the industrial administrator can arbitrarily make this type of decision without serious repercussions. As a result, many highly desirable improvements in methods must be initiated in so slowed down a fashion that the significance of the change is frequently minimized.

TECHNIQUE 1. Process Charts

Graphic presentation is very often used in methods analysis. The basic function of the process chart, as defined by one of its earliest proponents, Frank Gilbreth, was to serve as "a device for visualizing a process as a means of improving it." Lengthy verbal descriptions are, obviously, unwieldy for rapid and accurate appraisal of complex industrial operations. Synthesizing the essential process ingredients into an easily prepared and readily comprehended chart facilitates scientific motion study.

The widespread use of this technique has resulted in a multiplicity of charts geared for a great variety of purposes. Among some of the better known are product process, form process, flow process, gang, man-machine, multi-activity, and numerous other versions of process charts. Fundamentally, all these devices have a common structure. Then too, they all reduce to symbolic form the essential elements of an activity cycle and show graphically how these elements are interrelated.

Therblig symbols, while extremely useful for the concise presentation of elemental motions, have a serious limitation in certain phases of methods analysis. This is particularly the case when an entire process or major component thereof is being analyzed. Consequently there

has been a strong tendency to reduce the number of symbols used in this type of study. A measure of standardization has been effected, with the following symbols being generally accepted by most process analysts.

○ Operation

⇨ Transportation

▼ Storage

D Delay

□ Inspection

△ Uncontrolled action

The symbol ○ represents a broad category of actions such as the modification of an object's form by any industrial process. When administrative or supervisory actions are subjected to process analysis, *operations* include the acts of planning, deliberating, commanding, and receiving orders. Very frequently small letters and numbers are inserted within the large circle to designate specific operations. Such labeling serves to identify the various actions for subsequent differentiation between necessary and superfluous operations.

The transport symbol is probably the least standardized in this group. In addition to the ⇨ symbol, a ◻ or "closed U" designation is sometimes used to represent the movement of objects from one work place to another. Several alternatives have also been suggested. For example, some authorities prefer to use a large circle Ⓣ with the letter T inserted. Others recommend using a small circle o, presumably to avoid confusion and to simplify the graphic technique.

The storage symbol ▽ is likewise frequently modified. The chief cause for lack of uniformity is the difference in degree between temporary and permanent storage. Some analysts prefer to insert the letters TS (temporary) or PS (permanent) to differentiate the types of storage. Others suggest, in addition to the single inverted triangle ▽, a double inverted triangle ▼, to represent temporary or permanent storage, respectively.

The delay symbol D is sometimes omitted; its function being incorporated in either the storage or uncontrolled-action symbols.

Inspection, shown by a square □, is frequently differentiated by a letter or number code inserted in the symbol. This serves to designate the specific examinations of an object verifying its conformity or nonconformity to prescribed norms. A recent innovation in symbolization of this activity suggests turning the square so that it rests on an angle ◇.

The final symbol △, representing an uncontrolled activity, is not

always included in process analysis. Since such activity is outside the scope of investigation, its inclusion might be considered superfluous.

Having agreed upon a set of symbols, the next step consists in the dissection of a given operation to determine the exact operations, etc. A process chart is generally used for this purpose. The chart usually has the pertinent symbols listed in one vertical column together with a parallel column giving an explanation or description of the action. While this might seem to be a duplication, the inclusion of the descriptive information frequently is necessary to determine the action's importance to the operation. Additional columns can also be used to show (1) the distance an item is moved, especially when the action refers to transport; (2) the number of items being worked upon, stored, moved, or inspected; (3) the time factor; and (4) the equipment requisite for that activity.

There is a very great variety in the types of charts used in process analysis. A few of the better-known forms will be discussed in the subsequent techniques. Despite the variance, however, the structural pattern of all process charts is very similar. The charting, in Exhibit 12-3, of a very simple operation, the placing of a case of tomatoes on the shelves of a supermarket, should serve to highlight the essentials of this technique. The data listed include symbols, activities, and related times and distances involved in this relatively simple task. Basically, this illustration might be termed a process flow chart since it lists the activities in a chronological and action sequence.

Obviously, this rudimentary analysis is not intended to serve as a precise measurement but rather as an illustration of the important process-analysis principles. The summary of this sequence shows the following data:

1 uncontrollable action
5 delays
6 operations
5 transports
3 inspections
1 temporary storage
1 permanent storage

An analysis of time and distance indicates that the six transportation actions involved moves totaling 218 feet requiring 3.8 minutes. The six operations consumed 2.7 minutes.

These data serve no purpose unless, through the analysis, inferences can be made regarding the efficiency of this particular operation. Presumably, a study of the elemental activities and their time and dis-

tance factors should lead to the development of methods improvement. When such improvements are made, the function of process charting is fulfilled.

The relatively simple example presented here should be adequate to call attention to several inherent limitations of this device. Even though this type of operation is very commonplace, and apparently

Exhibit 12-3. Process Chart

Symbol	Distance, ft	Time, dec-min	Activity
		0.2	Told to get case of tomatoes, can No. 303 from storage
		0.4	Customer asks question
	40	0.8	Get hand truck
		1.2	Smoke cigarette
	80	1.3	Move hand truck to storage area
			Locate case in storage
		1.2	Select proper case
			Bump other case loose; case falls on floor
		0.5	Replace fallen carton
		1.6	Smoke cigarette
		0.2	Place case on hand truck
	60	1.1	Move truck to store aisle
		0.8	Encounter customer "road block"
	20	0.3	Move truck to tomato section
		0.3	Open case
		0.1	Check cans for imperfects
		1.2	Place cans on shelf
			Cans on display, for sale
		0.1	Check arrangement
	18	0.3	Move hand truck out of way
		0.3	Dispose of empty carton
		1.8	Smoke cigarette

very simple, more than 22 distinct activities were differentiated. A more careful analysis would probably double this number simply by more precise differentiation. Moreover, if the study reverted to the use of therbligs, the number of elemental motions would undoubtedly be counted in the hundreds. Consequently, this type of analysis should be restricted primarily to routine-type sequences which occur very frequently and which entail significant aggregate costs. Study of an infrequently performed work cycle would, obviously, have minimal value

except for research purposes. Studies such as the one described, while illustrative, can hardly be justified on economic grounds. Where operations are nonstandardized, the incidence of variables generally makes process analysis a haphazard venture. While studies in this sphere might be of great value in isolating specific variables and then in reconstructing the operation along a more efficient pattern, most nonstandardized operations do not lend themselves to economically justifiable process analysis.

On the other hand, in those instances where process analysis can be properly applied, this technique makes possible both the systematic and the scientific construction and reconstruction of work patterns. The benefits of such precision in determining optimum industrial routine are invariably evident in improved productivity.

Types of Process Charts. One of the clearest differentiations among the basic types of process charts is that presented by Gerald Nadler in his text *Motion and Time Study*. Dr. Nadler's classification includes:

1. Product process charts
2. Form process charts
3. Man process charts
4. Operations charts
5. Multi-activity charts

The first two types are identical except that in the first instance the process pertains to "the symbolic and systematic presentation of the procedure used to modify and/or work on a product," [2] while in the second case, forms are the object of the action. The last three categories are similar in that they deal with workers and specific methods of operation. In man process charts the job requires the worker to move from one work station to another. Operations charts are concerned with employees at fixed work places where the equipment used is not cycle-time controlling. Multi-activity charts are defined as "symbolic and systematic presentations of the method of work performed by a man when his work is coordinated with one or more cycle-time controlling devices such as another man, a machine, machines, etc." [3]

The rather wide latitude in respect to the cycle-time-controlling forces means that there are numerous modifications of multi-activity charts. Once again Nadler's classification sets up a logical progression, namely:

1. Man and machine charts
2. Man and multi-machine charts
3. Multi-man charts

[2] *Ibid.*, p. 124.
[3] *Loc. cit.*

4. Multi-man and machine charts
5. Multi-man and multi-machine charts

Needless complications would result from any attempt to compress explanations and illustrations of all the versions of process charts into this single chapter. Consequently, only two of these basic process charts will be described in greater detail.

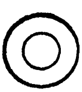
TECHNIQUE 2. Flow Chart and Diagram

The sequence of activities from one work station to another can be indicated by means of flow charts and diagrams. Such a chart or diagram provides a graphic view leaving very little to the imagination as to where specific activities are to be performed. Distances and dimensions can readily be set forth to scale. The flow diagram is a useful adjunct particularly when layout modifications are to be made. When used in this capacity the flow diagram synthesizes the basic data shown in the flow process chart. In turn the flow diagram becomes the framework for the actual template layout.

Direction of work sequences can easily be shown in flow charts and diagrams by lines indicating movement from one work station to the next. This feature is extremely important since it provides a factual basis calling attention to unnecessary activities, particularly to backtracking and extremely long moves. Redesigning the work route frequently results in fewer and shorter moves. Comparison of revamped and simplified flow sequences with the original process arrangements is generally sufficient to demonstrate the superiority of the systematically designed flow over the process developed by hit-and-miss methods.

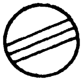
Typical of most management techniques, flow charts and diagrams have long been associated with manufacturing industry. More recently, systems analysis of office procedure has emphasized the value of this technique for paper-work control. The increasing complexity in the broad field of informational control has practically made mandatory the more extensive application in this area of techniques such as the flow chart and flow diagram.

As was previously mentioned, there is no uniformity in respect to the symbols used in either process charting or process diagraming. In the office-management sphere the following symbols seem to be most commonly used:[4]

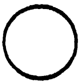


Origin of a record. This symbol indicates an operation wherein significant information is first placed upon a blank form.

[4] *Systems Analysis: Modern Planning for Clerical Functions,* The Standard Register Company, Dayton, Ohio.

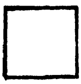


Change in record. This symbol states that information is added to or deleted from an existing record.

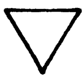


Handling operation. Record keeping involves numerous nonproductive operations such as sorting, folding, separating, attaching, etc.

Move. A smaller circle with the insert "to" refers to a movement of the form from one person or work place to another.



Inspect. This operation pertains to the control of quality in the form in question. Checking, verifying, reviewing, and similar activities are in this category.

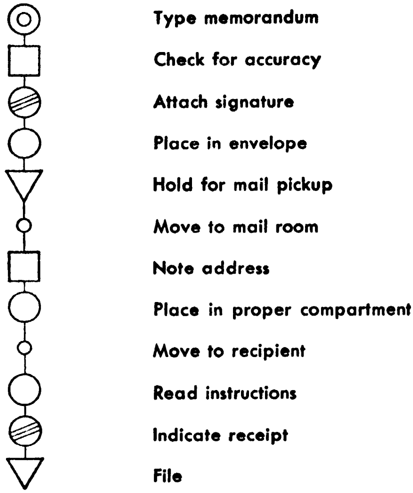


Delay. Any interruption to the prompt and orderly sequence of the record form through the process. Filing, holding, setting aside are illustrative of this symbol.

The genesis in paper-work simplification from a descriptive form to a process chart and then to a flow diagram can best be seen in a specific illustration, showing the basic components in the process of communication between two departments. It can be assumed that a complete description of the operation in narrative fashion would probably require a hundred or more words. Exhibit 12-4 condenses the unwieldy and costly narrative method into a process chart. The logic and mechanics of this technique have already been explained. The next step is to arrange the symbols on a simple horizontal plane, at the same time holding rigidly to the sequence established in the process chart. The left-to-right sequence of this single-line procedure flow chart, as seen in Exhibit 12-5, seems to add nothing to what has already been accomplished. However, upon closer study, it becomes evident that this horizontal arrangement adds, as it were, a new dimension, permitting the expansion of this form by adding other single-line sequences. Thus, if in our illustration copies of the memorandum were to be sent to a superior and a customer, the sequence might be modified as shown in Exhibit 12-6. The sequence is of necessity abridged. Copy 1 is signed, sent to the mailing office, stamped, etc., and sent to the customer. Copy 2 first goes to the immediate supervisor for his signature and notations. It is then sent to the subordinate who is to deal with the specific customer's problem. Copy 3 is retained by the person initiating the action.

From this relatively simple expansion of process chart into flow diagram, it should be evident that as additional copies of a form must be

Exhibit 12-4. Flow Chart



processed and as more individuals and departments are involved in an increasing number of operations, the flow diagram can become considerably more complex. Despite this seeming complexity, however, once the fundamentals of the diagraming technique have been mastered, this procedure has many advantages over detailed analysis and instructions in descriptive form or in process chart form.

The next phase in this sequence can, if deemed necessary, be the pictorial presentation of the process flow in diagram form. While this technique can become time-consuming and costly if every movement is recorded and if dimensions are rigorously kept to scale, for most purposes such precision is seldom mandatory. Exhibit 12-7 shows how the information contained in the procedure flow chart can be converted into a relatively simple flow diagram.

The action is seen being initiated in the upper-right-hand corner at the desk marked *a*. The memorandum is then given to a secretary *b*, who gives the three typed copies to the initiator *a*, who in turn has copy 3 put in the files *c*. Copies 1 and 2 are taken to the mail room. Copy 1 is processed as outgoing mail and sent to the customer. Copy 2 is delivered by intracompany mail to the pertinent supervisor. His secretary *d* has the supervisor *e* check the memo and make necessary

Exhibit 12-5. Procedure Flow Diagram

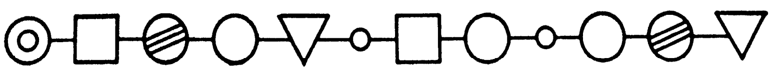
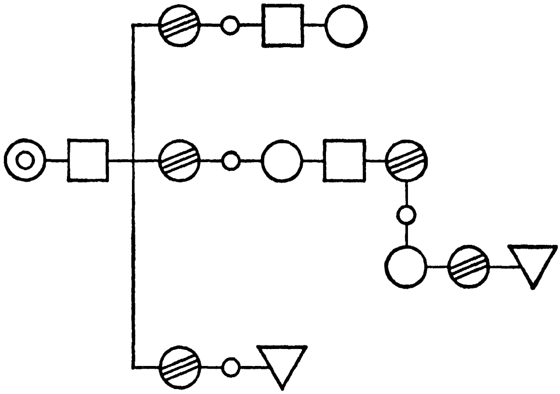


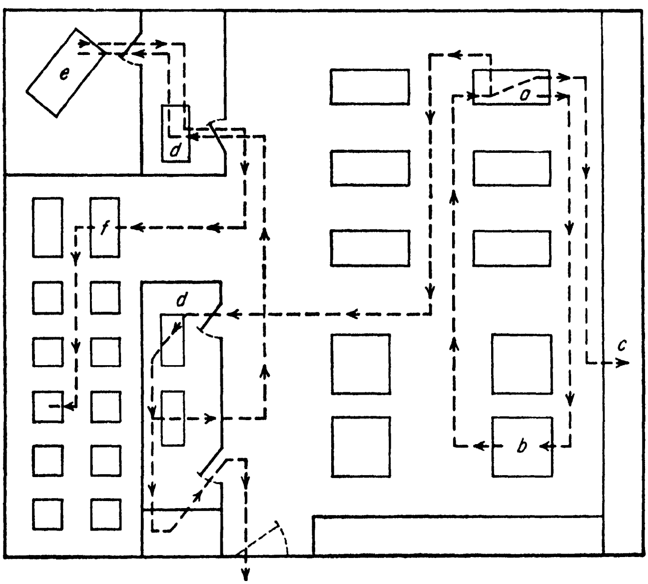
Exhibit 12-6. Procedure Flow Chart



notations. This copy is then sent for final processing to the section marked *f*.

Among the many reasons for the widespread use of flow diagrams in all phases of business and industry is their relative simplicity. There is no highly specialized competency necessary for construction of these diagrams or for their interpretation. Equipment and material costs requisite to proper use of flow diagrams are insignificant. The dia-

Exhibit 12-7. Flow Diagram



grams are easy to handle and to file for record-keeping purposes. As a rule, supervisors and employees have little difficulty in comprehending the information coded into the diagram. Finally, the decision maker has in the flow diagram an extremely helpful and timesaving tool.

TECHNIQUE 3. Operations Chart

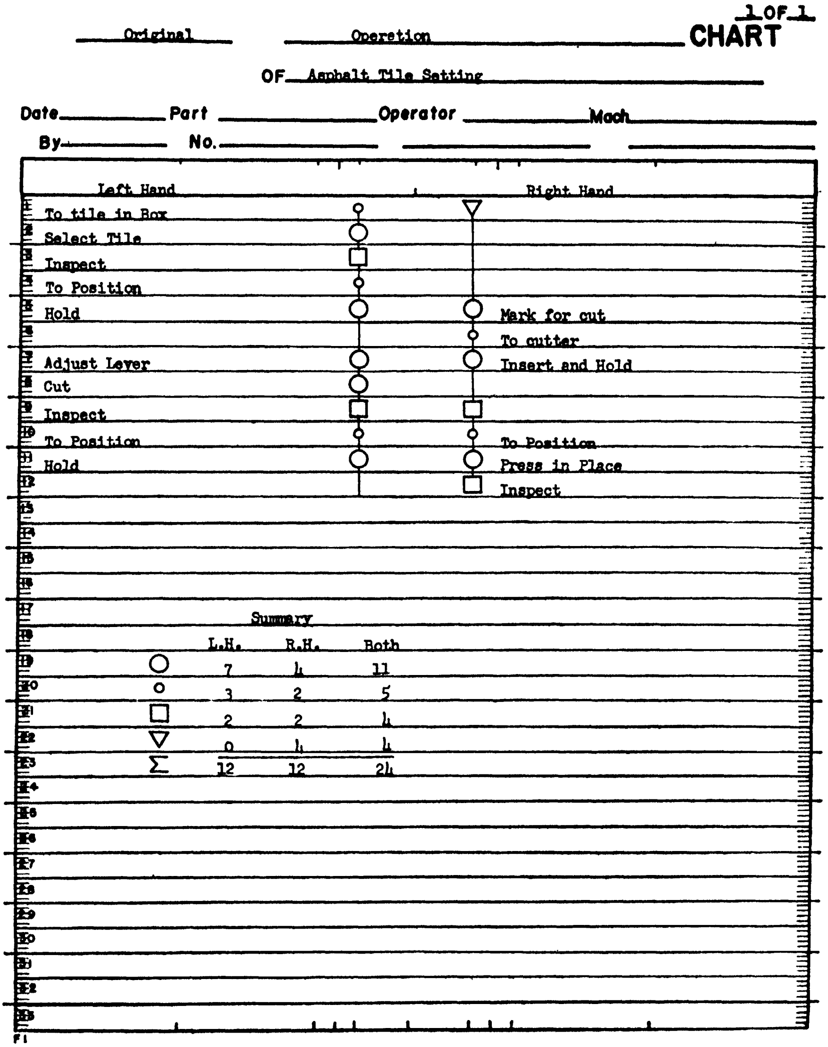
The operations chart is one of the most widely used variants of the process chart. It is an analysis of an industrial operation integrating several work sequences performed simultaneously at a given work place. This type of chart can show the sequences, symbols, time, and distances pertinent to a given work cycle, and it indicates how an operation is performed. From this graphic portrayal it is easy to discern the specific points at which materials and subassemblies are integrated into the production sequence. While this charting technique is used to depict some rather complex operations, a simple left-hand–right-hand type of chart will best illustrate the procedure for preparing and using an operations chart.

Exhibit 12-8 is a graphic description of cutting and placing asphalt tile on a floor. In the interests of clarity only one cycle is charted, and even this cycle is kept as simple as possible. The first column lists, in brief descriptive form, the actions performed by the left hand. The right hand's activities are similarly indicated in the opposite column. The two center rows merely convert the descriptions of the actions into their respective symbolic forms. The graphic version facilitates comparison and analysis to locate unnecessary actions. The summary at the bottom of the sheet gives a concise picture of what each hand contributes to the operation. Note that activity or inactivity which continues over a longer period is counted several times. For example, the initial inactivity of the right hand is counted as 4, that is, equal to the number of actions completed by the left hand during the interval the right hand was idle.

Where the work cycles are repeated often enough, and where the labor and equipment costs warrant, steps can be taken to redesign the functions of operatives so that there is a balance in the activity cycles. Such balance is an absolute necessity, for example, in the so-called mass-production industries. Actually, any activity depending upon serialization and synchronization needs precise determination of times and sequences. This requisite is equally valid for all four basic production processes: analytic, synthetic, conditioning, and extractive.

Translation of all the elements comprising an operation cycle into graphic form facilitates the juggling of these components into more

Exhibit 12-8. Operation Chart



effective combinations. It also assists the scheduling agent in his function of allocating specific tasks to designated individuals and machines. Unless the scheduling agent has a factual base upon which to allocate the available resources, he will naturally revert to guesswork. Thus the availability of reliable operations charts increases the probability that scheduling will be more effective. As a result, production planning becomes more meaningful. The decision maker's function of selecting

and utilizing the economically preferable industrial process is given a scientific base.

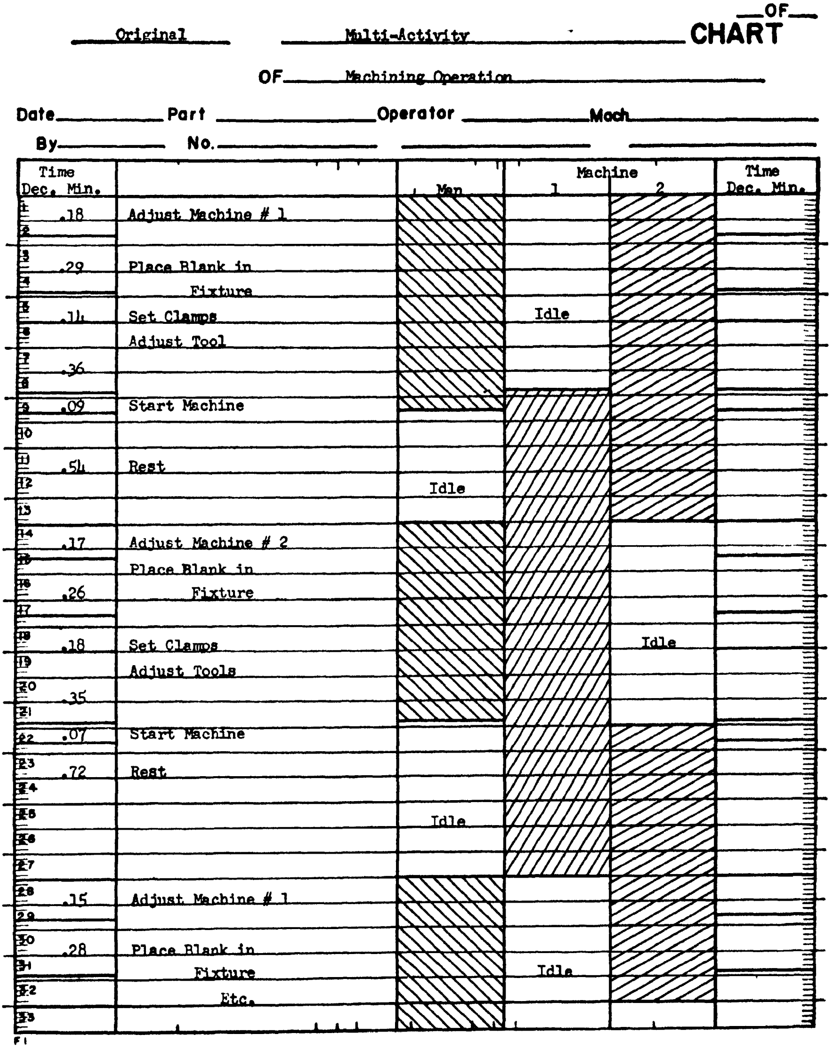
TECHNIQUE 4. Multi-activity Chart

As the term implies, this form of process chart pertains to the symbolic representation of the work sequences performed by a man in conjunction with a machine or with several machines or by any combination of men and machines. From this graphic illustration idle or excessive time can easily be spotted. The basic purpose of multiple-activity charts is to call attention to wasted motions and lost time caused by the inability to integrate into a balanced work cycle the contributions of specific men and machines. The imbalance having been recognized, the logical procedure calls for redesigning the activity sequence so that the work cycles for the men and machines in question are put into a more effective arrangement. Invariably, this type of chart has a special vertical column for recording the beginning and ending times of each activity as performed by each agent. The method for calculating these times will be discussed in the next chapter. In effect, charts of this sort are actually tools of both operations analysis and work measurement.

As can readily be inferred from the great variety of man-machine combinations that are found in industry, no single illustration of a multi-activity chart could incorporate all the features of this technique. One of the commonest, and probably the easiest, versions of multiple-activity charts to comprehend is the man-and-machine process chart. The operator's activities are set forth in sequential fashion with the symbols, descriptions, times, and distances being listed in separate columns. In addition, the machine cycle is also included. This permits the analyst to note the current method used to integrate man and machine contributions.

Exhibit 12-9 depicts one version of the multiple-activity chart. In this machining operation, the operative tends two machines. The time scales at either side of the chart measure the elapsed time requisite for performance of each elemental activity. It will be noted that in the first two cycles, out of a total of 3.35 minutes, the machine tender rests 1.26 minutes, or approximately 38 per cent of the time. Cumulatively, this amounts to about 3 out of every 8 hours worked. Assuming that the productive activities have been properly timed, with adequate allowances for fatigue, etc., then presumably machine-caused rest intervals of 38 per cent of total time seem somewhat out of proportion. Following the same procedure, the productive and idle times of each machine can be studied to see if the operating cycles are optimized.

Exhibit 12-9. Multi-activity Chart



When necessary for improved performance, the man-machine combination should be rearranged. A careful study of the multi-activity chart is a beginning point for this type of methods improvement. The charts can also be used to show the more likely alternatives.

It has previously been stated that the objective of methods analysis is attained when the effectiveness of performance is improved by eliminating unnecessary motions, by combining related activities, or by

substituting new and more effective methods in place of time-wasting sequences. This objective becomes more difficult to attain as the scope of operations broadens to include more and more men and machines. Multiple-activity charts help condense the steadily expanding voluminous descriptive data into capsule form. The requisite information in this abbreviated yet concise graphic version greatly facilitates the decision maker in the methods-analysis sphere to make better decisions more promptly.

TECHNIQUE 5. Micromotion Study

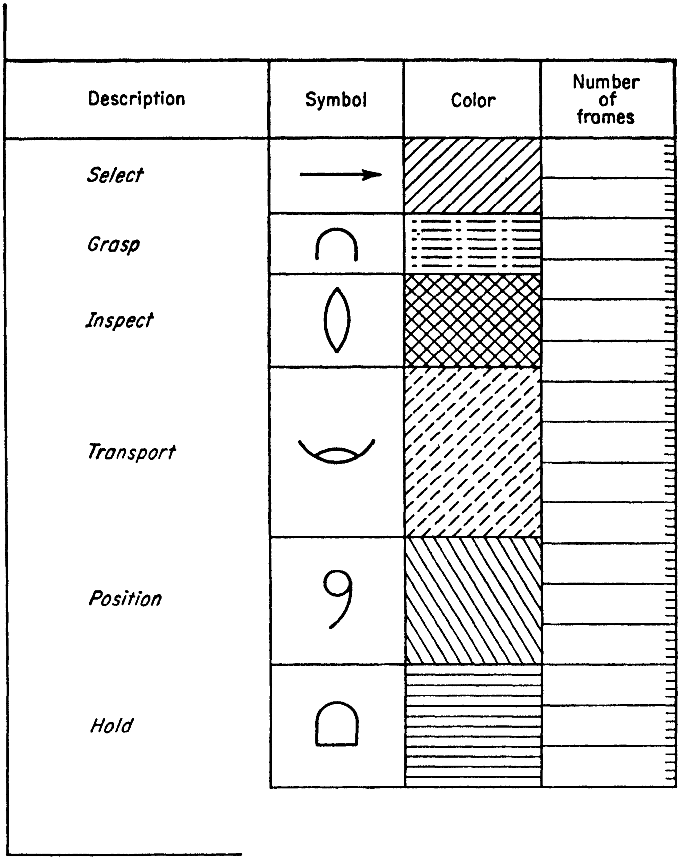
This technique, developed by Frank Gilbreth just prior to World War I, is fundamentally a therblig chart except that the motions in the work sequence are recorded on photographic film. The motions are then isolated, are given therblig designations, and are ascribed specific times as measured from the film. Two basic timing techniques are commonly used. In the first, a microchronometer is placed strategically so that the clock face is filmed together with the worker in motion. As the operation continues to be filmed, changes in time are automatically recorded on the film. This permits easy calculation of each activity's time by simply noting beginning and ending times for the particular activity. While this technique has some obvious advantages, it is nevertheless cumbersome and inflexible, particularly because the microchronometer, or clock, must always be clearly visible on the film. The second alternative recording method also includes filming the operation. Subsequently the frames elapsing for each of the operation subdivisions and for the therbligs are counted. Since constant speeds are used in the photographing, establishing the time per frame permits relatively simple calculation of the time elapsing for each activity sequence and for the entire work cycle.

Simo Charts. A number of variations of the basic micromotion technique have been introduced into methods analysis. Among the better known of these micromotion modifications is the simultaneous motion cycle chart, usually referred to as the simo chart. Basically, the simo chart merely incorporates the time factor into the conventional therblig chart. This systematic arrangement of therbligs, their symbols, and associated times provides a factual basis for methods study. Motion pictures are generally used to record the action cycle. This type of analysis can be rather expensive; hence it is restricted to situations where the volume of work is considerable and where the element of dexterity is important. Such portrayal obviously has value for training purposes and for analysis of specific job difficulty.

Once the filming has been accomplished, the simo chart can readily

be constructed first by identifying and isolating the specific cycle on the film. The various therbligs are then listed in sequence and shown graphically on the chart. Time values can be ascribed by merely noting the frames elapsed and multiplying this figure by the time factor

Exhibit 12-10. Portion of Simo Chart



or standard applicable per frame. Exhibit 12-10 illustrates the simo chart's basic components.

The chart's four columns, labeled description, symbol, color, and number of frames, provide very useful information about the elemental components of an operation. The portion of the simo chart shown pertains to the asphalt-tile-setting procedure previously described and graphed as a right-hand–left-hand, or operations, chart.

In order to keep the presentation simple and concise, this example is necessarily fragmentary in size.

The six basic motions listed in the first column are part of the tile-laying sequence. These motions are shown in symbolic form in the second column. The crosshatching, etc., in column 3, is intended to represent, as shown in Exhibit 12-1, the various colors by which therbligs are sometimes differentiated. The last column is an allocation of film frames to each elemental motion. The sequence of six therbligs, in this case, covered 80 frames. The action of selecting was recorded on the first 9 frames, the grasping motion on the next 7 frames, and so on. Since presumably the photographing was done at a constant speed, each frame has a standard time value. Relative and total times can thus easily be computed. Motion economy begins with just such seemingly insignificant minutiae. However, it is through this procedure that the operation can be objectively appraised and measures for improvement can be initiated.

It should be noted that in simo charting there is a rather careful subdivision of work with a logical progression from operations to subdivisions and thence to therbligs. This detailed analysis is conducive to scientific methods study since the key sequences for each hand can generally be identified. Isolating the key sequences facilitates rebuilding the activity cycles by eliminating or modifying the less essential components. The objective in this rearrangement is not only to secure the best work pattern for one hand or for one operative but to secure the best balance in sequence of operations for the entire complement of men and machines.

Chronocyclegraphs. The chronocyclegraph is considered by most methods analysts as strictly a laboratory technique with little practical industrial value. The complexity involved in preparing chronocyclegraphs is the basic reason for this attitude. This device, nevertheless, is considered as the most accurate of all the techniques used to study paths of movement, particularly for short-cycle, highly repetitive operations. In some respects this technique resembles micromotion analysis, particularly in its reliance upon photography. Lights are attached to the operator's hands, and a single integrated picture is taken of the path of movement. This single picture of a series of actions is obtained by keeping the camera shutter open for the whole length of the cycle. The photographed design can then be studied to note interferences in the symmetry of operations. Where hesitations or sudden shifts in motion occur, the analyst can suspect unnecessary and handicapping motions.

Wherever possible, stereoscopic cameras should be used so that the

work pattern can be viewed in three dimensions. In addition, special "interrupted" lights are needed. The most practical lighting apparatus is a relay-operated type which imparts a special lighting effect to the path of movement. The interaction of a condenser and high-speed relay first steps up the lighting, causing a brilliant flash, and then allows a gradual diminishing in lighting intensity. This gives the trailing effect to the pear-shaped light dots which are useful both for noting the direction of movement and also the relative times required.

The name of Frank Gilbreth is also associated with the development of this technique. While the basic principle had been introduced and perfected by professional photographers, it was Frank Gilbreth who adapted the chronocyclegraph to industrial application. For a long time its cost and complexity restricted this device to very special situations. Recent improvements have, however, led to a standardization of procedure which might make the chronocyclegraph a more practical tool for methods analysis.

Memo-motion Study. Memo-motion study, a relatively recent technique introduced in the 1950s by Dr. Marvin Mundel, is actually a variation of micromotion study. Motion pictures, taken at relatively slow speeds, usually at the rate of 1 frame per second, are later shown at controlled speeds, for example, at 100 frames per second. This control allows recording of times in hundredths of a minute, thus facilitating computations. As is to be expected, this technique has most of the advantages and limitations of the broader category of micromotion studies. Permanent records are secured and, in this case, at a fraction of the time and costs normally associated with photographing of industrial operations.

Although it can be rather costly, memo-motion study can be particularly useful where pictorial presentation is necessary. Generally memo-motion can be used only when the operation is:

1. Technologically stable, hence unlikely to be modified within the near future
2. Repetitive and frequently employed
3. Important from an output and cost point of view
4. Not easily or accurately measurable by other means

The memo-motion study sequence should begin with the usual "amenities" such as notifying the workers concerned of the project's purpose. The specific work cycles to be filmed should, obviously, have been determined some time in advance. Estimates should also have been made regarding the number of times each cycle should be photographed. The actual filming should be done in accordance with sound photographic practice.

For proper analysis of the memo-motion films, each element of each operation must be carefully identified and recorded on a chart. Recording is facilitated by using therblig symbols, which were described in previous techniques. The chart listing the sequence of elements provides the information requisite to deciding what elements are superfluous. The addition of time values for individual elements is a logical step in this procedure. Comparison of actual times, adjusted by a rating factor, can be useful in calculating standard or base times for all the elements.

All the micromotion variants discussed in this section have several characteristics in common. They tend to be more expensive than the conventional methods. Costs obviously rise with the extensive use of photography. This is particularly the case when numerous cycles of a single operation must be filmed or where, because of frequent technological innovations, studies must be repeated. Not only are photographic supplies expensive, but items such as elaborate equipment for taking, processing, and showing the films can easily boost costs to uneconomic proportions. In addition, special skills are needed for all the recording and interpreting functions. Setting up the work area and making certain that the filmed sequence is truly representative also pose serious obstacles.

On the other hand, the permanency of the records is an important advantage. When controversy or uncertainty arises in respect to a particular work cycle, instead of being forced to make another visual study, the analyst can simply refer back to the original film.

Although the recording of work cycles on film has been treated in this chapter as an integral feature of micromotion analysis, it should be stressed, at this point, that micromotion study can also be ventured without using motion pictures. The essence of micromotion study is the reduction of operations into elemental components, or therbligs. The purposes and procedures associated with this technique have already been described. The addition of motion-picture technology is simply a refinement by which greater precision and better scientific results can be obtained from methods analysis.

ILLUSTRATION 1. "How to Be Efficient with Fewer Violins"[5]

The following is a report of a Work Study Engineer after a visit to a symphony concert at the Royal Festival Hall in London:

[5] *American Association of University Professors Bulletin,* vol. 41, no. 3, Autumn, 1955, pp. 454–455. Origin unknown, first published in the August, 1952, issue of the house organ of His Majesty's Treasury of the Courts, O&M Bulletin.

For considerable periods the four oboe players had nothing to do. The number should be reduced and the work spread more evenly over the whole of the concert, thus eliminating peaks of activity.

All the twelve violins were playing identical notes; this seems unnecessary duplication. The staff of this section should be drastically cut. If a larger volume of sound is required, it could be obtained by means of electronic apparatus.

Much effort was absorbed in the playing of demi-semi-quavers; this seems to be an unnecessary refinement. It is recommended that all notes should be rounded up to the nearest semi-quaver. If this were done it would be possible to use trainees and lower-grade operatives more extensively.

There seems to be too much repetition of some musical passages. Scores should be drastically pruned. No useful purpose is served by repeating on the horns a passage which has already been handled by the strings. It is estimated that if all redundant passages were eliminated the whole concert time of 2 hours could be reduced to 20 minutes and there would be no need for an intermission.

The conductor agrees generally with these recommendations, but expresses the opinion that there might be some falling off in box-office receipts. In that unlikely event, it should be possible to close sections of the auditorium entirely, with a consequential saving of overhead expenses, lighting, attendance, etc. If the worst came to the worst, the whole thing could be abandoned and the public could go to the Albert Hall instead.

Following the principle that "There is always a better method," it is felt that further review might still yield additional benefits. For example, it is considered that there is still wide scope for application of the "Questioning Attitude" to many of the methods of operation, as they are in many cases traditional and have not been changed for several centuries. In the circumstances it is remarkable that Methods Engineering principles have been adhered to as well as they have. For example, it was noted that the pianist was not only carrying out most of his work by two-handed operation, but was also using both feet for pedal operations. Nevertheless, there were excessive reaches for some notes on the piano and it is probable that re-design of the keyboard to bring all notes within the normal working area would be of advantage to this operator. In many cases the operators were using one hand for holding the instrument, whereas the use of a fixture would have rendered the idle hand available for other work.

It was noted that excessive effort was being used occasionally by the players of wind instruments, whereas one air compressor could supply adequate air for all instruments under more accurately controlled conditions.

Obsolescence of equipment is another matter into which it is suggested further investigation could be made, as it was reputed in the program that the leading violinist's instrument was already several hundred years old. If normal depreciation schedules had been applied the value of this instrument should have been reduced to zero and it is probable that purchase of more modern equipment could have been considered.

QUESTIONS

1. Can you infer from this article that the principles of organization and efficiency do not apply to violins and violin players?
2. How does a violin virtuoso make use of methods analysis?
3. Is there any logic to this article's comments on obsolescence of equipment?

ILLUSTRATION 2. Assembly of Car Radios[6]

Although the term *one best way* has been referred to frequently in this text, it should be remembered that this concept does not imply absolutes, either as to perfection in method or to universality in use. In the dynamic industrial world very frequently what constitutes the "one best way" for one concern does not even approximate the ideal for its competitors. A relatively recent *Business Week* article highlighted this fact by comparing two up-to-date companies, Delco Radio Division of General Motors and the Motorola Corporation, that use rather dissimilar methods to produce similar products, namely, small radios. Production of these radios in both companies is currently geared to average between 1,200 and 1,500 finished units per day.

Delco Radio Division of General Motors Corporation uses a 46-station Dynasert machine to perform 46 successive assembly tasks. Mechanical contrivances have replaced workers in feeding the materials, making the necessary connections on the printed circuit boards, and performing all other operations. However, since less than 50 out of the 193 assembly steps required in the making of a car radio can presently be mechanized, there is still considerable hand fitting at certain phases of the operation outside the automated 46 sequences performed on the Dynasert machine.

Motorola avoids the highly mechanized stage by stressing preassembly of certain components that can later be joined to the printed circuit base. This concentration on subassemblies, Motorola contends, gives a flexibility which is lost when extreme mechanization is adopted. Some of the preassembled packages of resistors and capacitors are so arranged that a worker can install a dozen or more by a single motion. Even more important, the company believes that product design can more easily be modified as style factors or technological advances require. This view is, however, counter to the premise that high-volume standardized products can generally be manufactured at lower cost by mechanized means.

Despite this basic difference, both concerns have many operational similarities. For example, both use the printed circuit board, a lami-

[6] Adapted from *Business Week*, Apr. 27, 1957.

nate of paper and phenolic plaster, about 1/16 inch in thickness. This is bonded to copper foil, and the wiring circuit is printed on the copper. The superfluous copper is then etched away, and the remaining copper lines provide the requisite wiring pattern. Despite somewhat higher material and processing costs, this technique is now almost universally used in the radio and television industry.

Motorola's prepackaging device is, obviously, an adaptation of mass-production methodology minus the extreme mechanization. Nevertheless, it should not be assumed that Motorola is entirely committed to hand assembly. For example, its "lazy susan" soldering machine makes 140 connections on the circuit boards in 7 seconds, replacing 30 hand-soldering stations.

The prime limitation of Delco's mechanization is the cost of its three supermachines, totaling nearly $750,000. The operations, including leading wires through specific holes, are highly subject to malfunction. Failure of one insertion head, because of some imperfection such as a tangled or bent lead or a wire off center, shuts the entire mechanical assembly line. Delco maintains that their three machines are in operation about 85 per cent of the time. In terms of cost, Delco is cognizant of the fixed-cost burden but feels that the volume justifies the investment. It estimates that the machines save half a cent in direct-labor costs per board over hand assembly although there is some question as to higher material and packing costs.

Business Week summarizes the controversy by pointing out that several electronics producers who have developed automatic assembly machines have had to delay installation because of economic considerations. In a number of instances compromises between the more and the less mechanized methods were effected by incorporating features of each. For example, in the car radio field, instead of complete mechanization, special insertion heads, operated individually, are sometimes used. In such cases a worker manually places a printed circuit board in a jig and, by stepping on a treadle, performs the requisite operation. While this is much slower than the automatic method and only one type of component can be inserted at a time, the lower capital cost and the greater flexibility give this hybrid technique considerable advantage.

QUESTIONS

1. How do you account for the two rather different production techniques in the same industry if the concept of the "one best way" is valid?

2. In this type of operation where 193 assembly steps are necessary, what are the advantages and the drawbacks to process charting?

3. Assuming the relationship as listed in Exhibit 12-11 between capacity utili-

zation and unit profit or loss for a specific component, what inferences might you make? Both fabricators x and y presumably have a maximum attainable capacity of 1,500 units per time period.

Exhibit 12-11

Capacity utilized, per cent	Net operating margin, cents per unit	
	x	y
100	2.5	0.7
95	1.5	0.5
90	0.9	0.4
85	0.5	0.35
80	0.2	0.25
75	0.0	0.20
70	−0.3	0.10
65	−0.8	0.0
60	−1.5	0.04
55	−2.4	0.09
50	−3.5	0.15

NOTE: In the interests of accuracy, it must be kept in mind that the above figures are strictly hypothetical and in no way reflect cost patterns at either Delco or Motorola.

ILLUSTRATION 3. Frank Gilbreth on Production Practices

As they now approached the Chelsea job the new scientific angles involved stimulated in Lillian an interest she had never before had in construction work. The work consisted of the erection of six buildings for Atwood and McManus, and was probably the largest wooden box factory in the world at that time. Work got under way on schedule in mid-winter weather—around Christmas of 1908—and was rushed to completion in four months under difficult weather conditions that caused delays. The brickwork was strictly high grade, with walls jointed on both sides. When completed, the job was credited by the owners as being an excellent piece of construction and as having cost them substantially less than it would have cost under the usual contractor.

By the arrangements Gilbreth worked out with the unions, bricklayers were taught the new methods of laying brick before the work began, and were offered a rate of $6.50 per day if they used them and accomplished the normal results to be expected. Otherwise they were to receive the union rate of $4.50 per day. Very few received the lower rate of pay because Gilbreth, believing the unions were right in opposing methods which permitted an inexperienced young man to earn more at skilled work than an older man who was often of greater value to his organization otherwise, had kept a workman of only

normal strength in mind in setting the figures. Not harder work, but methods that eliminated motions made the higher rate possible.

Fundamental to these methods was the new packet system by which the bricks were handled. By the old methods bricks that had been thrown hit-and-miss fashion onto a wheelbarrow were dumped on the bricklayer's platform. When the bricklayer picked up a brick he had to toss it several times in his hand to determine which was its top and which its bottom. He also had to figure out how to lay it to best advantage if its edges had been chipped from rough handling, or to discard it because its edges were too badly chipped for use on that spot in the wall.

By the new methods all bricks were so positioned in packets that the bricklayer could pick up each brick in the same way and place it immediately on the wall by the motions he had been taught. Chipped bricks were packed separately in identifiable packets for use where chipped edges were not important. The sorting and packing of the bricks were done by a cheaper grade of labor than bricklayers. Since the gravity conveyor for delivering the packets to the bricklayer's platform was not completed in time for use on the Chelsea job, packets were wheeled on wheelbarrows. The idea for, and the weight and size of, the packets originated in Gilbreth's mind from Taylor's and Gantt's packet system for handling pig iron. New methods by which motions were eliminated were Gilbreth methods, and Frank acknowledged Lillian's help in creating the whole pattern, especially where the packets were concerned.

When emptied, packets were so placed that each man's could be counted separately. Individual records were thus attained. Certain minor alterations were made in the Gilbreth Scaffold to adapt it to the packets. The handling of bricks from delivery at the construction job to delivery on the bricklayer's platform had been subjected to careful analysis—a type of analysis that led Gilbreth, a few years hence, to invent the process, or flow, chart which has such wide use today.[7]

With Gilbreth standardization, whether in surgery or industry, always meant methods of work that retained capacity for flexibility and growth, and were based in the fundamental idea that the human being was the most important element in work. When he went through the Ford automobile plant and saw the famous assembly-line methods in practice there, he was completely out of sympathy with the basic approach. In assembling his braiding machines at the Butt Company he had incorporated the principles of the proper workplace as he created it, that is, a workplace where every man's work was brought within the limits of his normal grasp area from a position comfortable for a human being to assume for long periods. All work could be arranged on that basic principle—and should be. But at the Ford plant he saw men at benches too low for them, men stretching farther than their normal reach, men in uncomfortable positions as they put on rear wheels, and much other evidence of making workers adjust to the line rather than

[7] Edna Yost, *Frank and Lillian Gilbreth: Partners for Life,* Rutgers University Press, New Brunswick, N.J., 1949, pp. 164–165.

making the line conform to the best needs of human beings. Management claimed that people adjusted to these things and did not mind, just as contractors kept saying bricklayers did not mind stooping for bricks. This was Gilbreth's idea of the wrong way to approach work, the wrong way to approach modern management problems—and he said so. In his philosophy and in his jobs, the operation was viewed from the standpoint of how to make it conform to the health—immediate and eventual—of the worker. He visualized an intelligent management refusing to take advantage of the fact that people can be conditioned to practices that are wasteful of human life and health. When someone tried to laugh him off by calling attention to the fact that a certain amount of work at an automobile plant had to be done by a man under a car, Gilbreth said why not position the car over a hole in the floor and let a man work in a man's normal posture.[8]

QUESTIONS

1. What are your sentiments regarding Gilbreth's insistence in using only workers of normal strength and attributes for the setting of work-load requirements?
2. Do you think Gilbreth would be in complete sympathy with the current automation fad?
3. Were the imperfections of the assembly-line system, as observed by Gilbreth at the Ford plant, necessarily integral to this method of production?

ILLUSTRATION 4. Westinghouse Electric Corporation

The cost-conscious manufacturer has a powerful urge to move from aged multi-story factories in crowded city districts to wide open areas where his dream plant can sprawl at one super-efficient level. But he needn't feel that all is lost if he finds he can't make the move. Staying put and remodeling the old plant in a modern likeness can have advantages, too.

Westinghouse Electric Corp. planned at one time to move its Meter Div. from a 75-year-old, four-story plant in Newark, N.J., to a North Carolina site where it could start from scratch with the latest in assembly lines. Then the plan was called off. Instead, Westinghouse put a much lesser sum into modernizing the old plant. It's pretty happy about it, too.

Straightened Out. Westinghouse did more than merely make the old quarters livable until the dream plant should materialize. It built some of the dream plant's most important features into the remodeling.

When the modernization is finished, a year from now, the Meter Div. will have an integrated production line, set up in slightly corkscrew fashion, in a completely modern factory that just happens to have an old shell. The main idea is to eliminate the back-and-forth flow of materials and products by fabricating complete subassemblies in each department successively.

The straightening of the production line as much as possible in a multistory plant is expected to cut elevator traffic by 75% and reduce the lift-truck fleet from 16 to four or five.

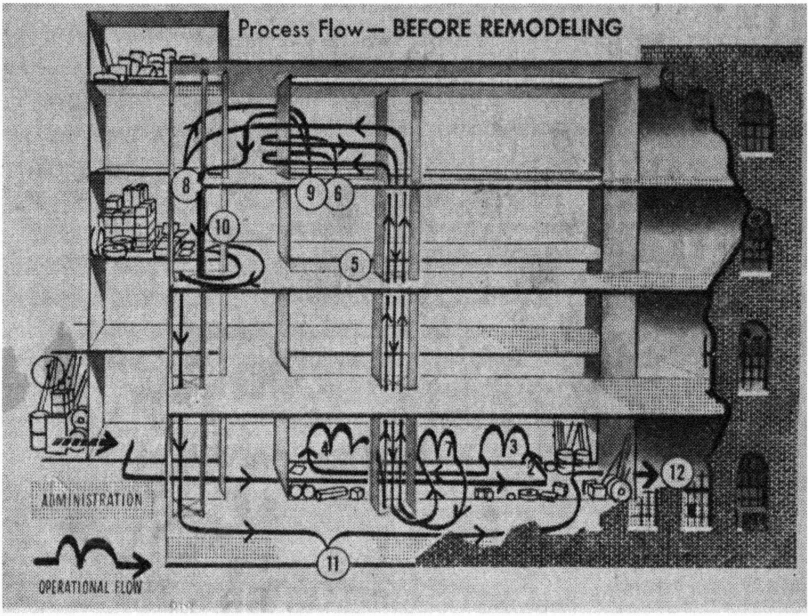
Big Savings. As the modernization got well past the halfway mark, Westing-

[8] *Ibid.,* pp. 246–247.

house officials discussed it for the first time at a recent meeting of the American Materials Handling Society in Newark. Besides the achievement of a modern production line in a 75-year-old plant, they mentioned two big savings of money and time:

A plant at the North Carolina site would have cost $5 million, plus another $2 million for moving expenses and for training employees. The remodeling

Exhibit 12-12. Process Flow—before Remodeling



Old route for manufacturing the case of a power relay brings steel stock from storage area (1), through cluttered courtyard (2) used as an overflow storage space, then to three manufacturing operations at (3), another two at (4). Elevator (5) takes parts to fourth floor to be degreased (6), then back to first floor for three more operations (7). Case then goes back by elevator to fourth floor to be plated (8) and painted (9). Finished case takes another elevator to storage area (10) to await shipment. After that, it goes back to first floor for packaging (11) and shipping (12). The old four-story plant has no conveyors at any point.

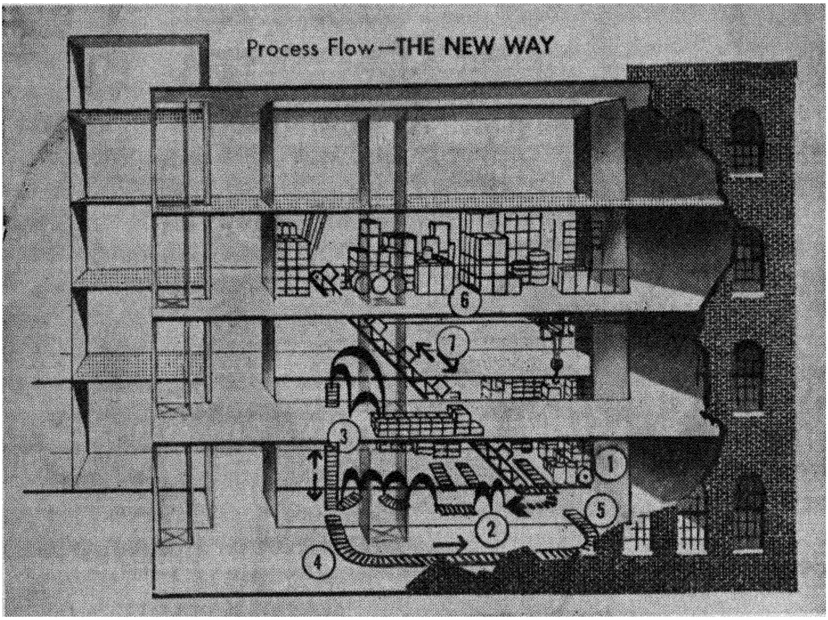
in Newark, turning the existing production line upside down and inside out, will cost about $2.2 million.

Moving from Newark to North Carolina would undoubtedly have cost days if not weeks or months of full production. The remodeling is being done without any loss of time. It takes longer this way—two years instead of the six months it would take if the plant were shut down during the work—but it's important for Westinghouse to be able to maintain normal delivery schedules on competitive items like power line relays and meters.

The more Westinghouse looked at the idea of rejuvenating the Newark plant instead of migrating southward, the more it liked the choice. Moving would have incurred a sticky problem of what to do with long-service employees. Besides, Newark seems to be on the upgrade as an industrial area, with stable taxes and an ample supply of skilled labor.

Unpromising. At the same time, Westinghouse was under no delusions that

Exhibit 12-13. Process Flow—the New Way



New route in remodeled plant shows fewer steps for the relay case. Steel stock are stored by the new punch-press department housed in the old courtyard (1). Fabrication is completed in one department as the pieces move down a conveyorized production line (2). The case makes its only journey upstairs, when it is taken to be baked and finished (3), then stored nearby until called for shipment. At that point, it goes down by conveyor to the packaging department (4), then by another conveyor to the shipping department (5). General storage on second level of new courtyard building (6) is reached by a new conveyor system (7).

the renovation would be easy. The Newark plant consists of 10 buildings sitting on four different levels around a courtyard that doubled as a shipping dock.

Probably more than half of the country's 80,000 to 100,000 factories are still of this old-fashioned multi-story design, haphazardly tacked together and almost impossible to convert into the single-level production flow beloved by modern designers. Many such factories get a paint job, some refurnishing,

new lighting, air conditioning, or the replacement of some old machines by later models.

What these halfway measures fail to provide is the real joy of creating a new plant—the gain in efficiency that comes from being able to lay out the production line from the beginning without regard for existing plant.

Westinghouse is trying to get this efficiency the harder way—by thinking of the production line in new-plant terms and then threading this production flow through its old multi-story buildings. This meant changing the meter and relay assembly operations from a job-shop type of individual assembly to a progressive-flow line.

Storage Problem. The company had a related problem, too. For lack of storage space for incoming materials, it had to rent a 40,000 sq. ft. warehouse five miles away. This put a strain on the shipping and receiving staff; it took 75 pickups and deliveries by trucks each day to keep things running smoothly.

Westinghouse engineers found the cure for this. It didn't look possible at first, but they found space in the old courtyard for a new two-level building four stories high. The second level is the new central stores area; an adjacent ground floor in one of the old buildings becomes the home of the shipping and receiving department. The former occupant, the punch press department, moves into the first floor of the courtyard building.

In its new quarters, shipping and receiving occupies a more accessible outside corner of the plant, where modern leveling docks can be utilized. It is connected with the storage area by a conveyor system; parts and materials move from the upper level storage area to assembly areas on gravity-feed conveyors.

Leveling and Shuffling. As in many other old factories, the Newark buildings were built on different levels, which raises hob with material handling. Lift trucks can't pass from building to building without awkward ramps or elevators. This is a handicap particularly on the ground floor, where the heavier manufacturing operations are carried out.

Westinghouse beat this problem by leveling its entire ground floor, except for one building that was a good half-story out of alignment. That building the company converted to offices. Any offices that didn't fit into this new space went to the fourth floor of the old factory, along with the laboratories and test facilities, leaving the lower floors for operations of more productive value.

The painting and plating departments, which used to be on the fourth floor for fire hazard or reasons of better ventilations, are being moved to the bottom floor, where they can be integrated into the production flow. In this age of better ventilation and air conditioning, the old reasons for putting these departments up under the roof no longer apply.

Intricate Shifts. S. C. Iannaccone, the Westinghouse engineer who is superintending the renovation, remarks that it takes someone with the mind of a three-dimensional checkers player to see that all these interrelated moves come out right without disrupting the plant's operations. But the gains in efficiency promise to make the nerve strain worthwhile.

For example, fabricating a relay case is a fairly simple operation. Yet this is what happened under the old setup:

The top piece of the case moved through three departments to shear, punch, and trim it; the bottom moved through two as it was blanked, formed, and bent to shape; the side, too, went through two departments as it was sheared and bent.

All these parts were then hauled to the fourth floor to be degreased, back downstairs to be welded together, and again up to the fourth floor to be zinc-plated, phosphate-coated, and finally painted. And the plant had no conveyor system between floors.

Now the complete operation, with the exception of a final jump to the second floor for baking and finishing, is done in one department, in one floor area.

Ticklish Move. The job of moving departments without interfering with production has been a juggling act far more difficult than laying out a whole new plant, Westinghouse engineers say.

Some departments, such as the central stores and the punch press room, are already in their new quarters. Others, such as meter assembly, are in transition, half working at new machines in the new location and the other half continuing at the old stand while the rest of the new stuff is being set up. Some departments, such as the plating department, haven't even begun to move.

Each new facility is fitted out with new machinery and material handling systems. Over a weekend, the department is then moved to the new location together with whatever old equipment is still scheduled for use. This way, the Meter Div. has managed to keep production going with no lost time.

Bright Future. Westinghouse engineers won't insist that, in general, they would rather have an old plant than a new one. But they have learned that for certain kinds of light manufacturing, a modern two-story plant may have advantages over the one-story plant, no matter what the books say.

Iannaccone mentions a couple of these advantages that are coming to light in the Newark conversion: (1) compactness and (2) consequently simpler material handling systems.

Westinghouse is confident of getting another 30 to 50 years of improved service out of a 75-year-old plant that had been destined for the wreckers.[9]

QUESTIONS

1. From your own experience, can you think of any plants that might benefit from action comparable with that taken by Westinghouse?

2. Does it seem feasible that instead of migrating southward, in the post–World War II period, significant components of the textile industry still in the north should have rejuvenated obsolescent facilities in similar fashion?

[9] "Turning an Old Four-story Plant into a Modern Assembly Line," *Business Week,* Feb. 22, 1958, pp. 70–72.

3. Is a new plant necessarily an efficient plant? Explain.

4. What contribution did the methods analysts probably make toward reaching the decision in question?

5. Show how these flow diagrams would provide more precise information if they were also depicted in process-flow-chart form.

CHAPTER 13

Work-Measurement—Time Study

DEFINITION AND DESCRIPTION

Work measurement is concerned with the application of quantitative, qualitative, time, and cost norms to a given sequence of purposeful activities. The terms *time study* and *time-and-motion study* are generally used to identify this function. However, the term *work measurement* seems to be more descriptive and more accurate. In essence, the broad topic of work measurement includes all phases of methods analysis and time study. The interrelationship of these functions should be apparent from the following progression of work measurement:

1. Identification of the specific operation
2. Analysis of that operation's components
3. Redesign of the activity cycle by rearrangement of components into alternative sequences
4. Selection of what appears to be the optimum alternative
5. Standardization of the activity sequences requisite to the optimum alternative
6. Measurement of the selected method's potential in terms of quantity and quality
7. Designation of standard times including actual operating time plus permissible allowances

8. Conversion of requisite time, effort, materials, and equipment into appropriate cost factors

The first six characteristics have already been discussed in the preceding chapter. While it is imperative in industrial application to consider all eight items as part of an integrated work-measurement function, it seems advisable for study purposes to separate the sequence into its methods and its time aspects. Nevertheless, it should not be inferred that these are autonomous functions. Even an incidental reflection upon the eight basic characteristics should show the interrelationship. For example, in item 4, selection of the optimum activity cycle presupposes norms of excellence. In turn, these norms can be selected only after costs have been properly considered. In every case costs are a function of the time necessary for completion of the activity cycle. Likewise, referring to item 6, it is not feasible to measure a method's quantitative and qualitative capacity without attaching time and cost norms. While some authorities seem to imply that methods analysis can be ventured even where careful time criteria have not been established, it seems more reasonable to assume that both methods analysis and time study are integral components of work measurement. Despite this inseparability in actual industrial practice, it does seem expedient for clarity in classroom presentation to view these two work-measurement components individually. Consequently, this chapter will place major stress upon items 7 and 8 of the preceding list. The first six items of this progression are presumed to have been discussed adequately in Chapter 12.

For more than half a century work measurement, and more specifically time study, have been practically synonymous with industrial efficiency expertism. There is logic in this association. Finding the best time for a given operation is, after all, the basic objective of industrial efficiency techniques. However, it should be noted that overemphasis on the time factor in industry can sometimes lead to inefficiency. This is the case when the shortest-time cycle results in inferior products or in friction in the work force. Employee hostility has, in numerous instances, been engendered by the misapplication of basically sound scientific-management techniques. Reference has previously been made to the trade unionists "revolt" against the post–World War I brand of efficiency expertism. The discovery by management, during that period, of some of the benefits of scientific methodology in industry blossomed into a full-fledged fad. Lack of adequately qualified analysts led to an influx of mediocrities, and even of some unscrupulous individuals, into this field. The obvious reaction took place. Even to this day there is a deep-rooted suspicion,

in most union circles, that the only purpose of efficiency experts is to squeeze extra effort out of the employees, with no thought of labor sharing in the increased productivity. Many managements still view these newfangled techniques as useful only in the extremely large enterprises or in the university classroom. Fortunately, the very rapid upgrading, particularly in the last ten years, of both line and staff personnel in most of our nation's enterprises has created a more receptive climate. These higher-caliber individuals, very frequently the graduates of specialized industry and university programs, have put techniques such as methods analysis and time study on a much sounder and a more legitimate functional basis. Consequently, there presently seems to be far less resistance to these "efficiency" techniques.

Misunderstanding as to the place, function, and procedure involved in motion-and-time study is not restricted solely to the labor and management fields. The public is even less cognizant of these scientific-management adjuncts. In fact, even the very founders of scientific management, in particular Taylor and Gilbreth, disagreed as to the scope and purpose of these techniques. It is understandable that Taylor in his pioneering ventures could not have foreseen all the ramifications of the new methods. When Frank Gilbreth amplified and refined the basic techniques and differentiated between the motion and time aspects, he precipitated a quarrel with the venerable Frederick Taylor. Initially Taylor referred to his ore-shoveling and related experiments as time studies. It was not until his 1912 congressional testimony that he referred to these same experiments as motion studies. It was at this time that Taylor, after becoming acquainted with Gilbreth's contribution, began to emphasize that "the study of elementary motions and the elimination of all false, slow, or useless motions were included in what he had earlier called time study." [1] The feud between the Taylor time-study group and Gilbreth's motion-study proponents continued for many years, even after Taylor's death in 1915. Early in the 1920s Gilbreth tossed a bombshell into the controversy by presenting a paper before the New York section of the Taylor Society. His paper "Time Study and Motion Study as Fundamental Factors in Planning and Control" bore the subtitle "An Indictment of Stop Watch Time Study."

In the intervening years the distinction between time study and motion study has been somewhat refined. Nevertheless, the intimate relationship perdures. In a sense Gilbreth's annoyance at the overemphasis on stop-watch time study has been proved justifiable. The

[1] Edna Yost, *Frank and Lillian Gilbreth: Partners for Life*, Rutgers University Press, New Brunswick, N.J., 1949.

incidence of error arising out of the misapplication of the stop-watch technique and out of human limitations was Gilbreth's chief objection to such work-timing devices.

Developments in this field within the past ten years have, in a sense, exonerated Gilbreth. The principles and procedures underlying synthetic or predetermined elemental times are reminiscent of the "one best way" and its emphasis on fundamental job components. It is highly probable that if Gilbreth could have foreseen present time-study and motion-study trends, he would have been very much pleased since his views have now been proved to be more scientific than were the contentions of the stop-watch advocates. On the other hand, this shift of current practice into the analysis and standardization of elemental work components should not be construed as an indictment of Frederick Taylor. It is only reasonable to assume that the earliest innovator could not have been cognizant of all possible future ramifications. Taylor, even though refusing to acknowledge them publicly, did accept Gilbreth's modifications. The Taylor-Gilbreth misunderstanding can be dismissed as a natural incident in an evolutionary process. However, it is hard to believe that more than thirty years elapsed between the inception of this feud and the widespread acceptance of predetermined elemental time techniques.

Despite differences in opinion as to work-measurement functions and techniques, even among the founders of scientific management, and despite some early mistakes in application, the basic ideas have become generally accepted. Evidence of this almost universal acceptance can be found not only in the production phases of large-scale industry but in practically every segment of business activity and even in numerous noneconomic activities. Gilbreth's motion-study experiments with disabled soldiers were initially viewed as a very laudable humanitarian gesture but with limited industrial application. Today comparable studies are proving their worth even from a utilitarian point of view. Hospital authorities have consequently become proponents of efficiency in the running of these eleemosynary institutions. The rapidly mounting costs of adequate hospitalization have practically made mandatory this adaptation of industrial efficiency techniques in nonindustrial spheres. The example of the changing patterns in hospital administration is typical of the trend in practically every area of human endeavor. Public administration could probably be cited as an even better illustration. The immediate acceptance by thinking citizens of the Hoover Commission's recommendations for efficiency in government indicates this attitude. Even more significant has been the relatively rapid conversion of most of those who were

initially apathetic or even openly hostile to this injection of industrial techniques into governmental activity. This statement seems to be substantiated by the fact that about four-fifths of all the Hoover Commission's recommendations have to date been put into practice. From this and similar evidence, the conclusion follows that work measurement, although closely associated with industry, is useful in every area where human beings expend effort in order to attain objectives.

The following sequence of the three basic time-study methods is not based on historical importance or degree of use. All three techniques have their strong points and their limitations. Selection of a specific technique should be made only after all factors, and especially cost and need for precise time standards, have been weighted.

TECHNIQUE 1. Stop-watch Standards

One of the most significant steps in the development of scientific work measurement was the adaptation of techniques previously used for timing entire operations to the timing of specific work cycles and job components. The practice of estimating by empiric methods the optimum time to be allowed for completion of entire jobs dates back to antiquity. However, the determination of average and desirable times for each job component is a relatively recent innovation. This precise measurement of times required for each part of a job became feasible only after accurate timing devices, and especially stop watches, became available. Then too, regardless of instrument availability, this practice could not become widely adopted until the scientific-management philosophy and principles were generally accepted and practiced.

The stop-watch techniques are so elementary that it does not seem appropriate to delve into a detailed description of procedure. Basically, there are three stop-watch techniques: (1) continuous, (2) repetitive, or snap-back, and (3) accumulative. The first method consists in an uninterrupted running and timing of the operation from the beginning to the end of the study. Elemental times are subsequently determined by subtracting the cumulative time at the beginning of the work element from the cumulative time at the end of that element. Exhibit 13-1 is an example of the basic procedure in continuous timing of a relatively simple work cycle.

The snap-back method, as the name implies, consists in an individual start-stop sequence for every element. After recording the elapsed time for the specific element, the watch hands are snapped back to zero. The independence of timing, regardless of element sequence, gives this method considerable flexibility and permits concentration upon one or more difficult or important elements. This saves consid-

erable time and cost, especially where the activity cycle is long and complex. The "interruption" characteristic also has other advantages. For example, since there is no great pressure to continue timing one element after another once the operation has commenced, the time-study men can get a better random sample of job elements and work cycles.

The accumulative technique uses two watches so connected that when one watch is recording, the other is automatically stopped. This facilitates reading of elapsed times with no interruption to the continuity of the timing operation as is characteristic of the snap-back

Exhibit 13-1

Activity	Accumulated time	Actual time
(Start of cycle)	3.24	
Adjust machine lever	3.32	0.08
Reach for material	3.43	0.11
Place material in position	3.69	0.26
Operate lever and machine	4.16	0.47
Release lever	4.28	0.12
Remove material from position	4.49	0.21
Inspect processed material	4.98	0.49
Place product in tote box	5.12	0.14
(End of cycle)		

All times in this illustration are decimal minutes. The 3.24 figure refers to the time recorded on the watch for previous activities. The 5.12 figure indicates the stop-watch recording at the end of this particular work cycle. Thus the cycle has been timed at 5.12 minus 3.24, or 1.88 minutes.

method. This technique is particularly useful when the job elements tend to be of longer duration.

Each of the three basic stop-watch techniques has its own advantages and limitations. For example, as can easily be inferred, the snap-back method must contend with errors injected by human factors in snapping back the watch hands at the end of an element. Foreign elements likewise tend to distort the correct timing. In particular, when many short-duration elements are involved, the snap-back method can result in complexity and confusion. Consequently, the continuous method, despite its higher clerical costs, is more acceptable because it is assumed to give a greater degree of accuracy.

Regardless of the specific method used, the timing implements can consist of (1) split-second stop watches, (2) minute-decimal stop watches, or (3) hour-decimal stop watches. The split-second type is

the best known. It is familiar to most individuals specifically because of its wide use in timing athletic events. The hour-decimal version, however, has a distinct advantage for industry purposes since the readings in terms of hour fractions conform to industrial practices of measuring operations in hour units. Regardless of which type of watch is used, it is fairly simple to translate from one unit to another by means of standard conversion tables.

There are additional uniform tools and procedures used in all three basic stop-watch methods. The time-study recording forms, although they might vary considerably, are integral to all the methods. Then too, the familiar observation board is an essential item. This board is so designed that the time-study man can move about with facility and use his hands for timing the operations while noting results on the form. On occasion slide rules might be considered standard equipment.

The procedure is similar in all three methods in so far as all the precepts of sound timing practice are applicable. For instance, in every case the jobs to be timed must fulfill the prerequisites of reasonable standardization and simplification even prior to the detailed analysis. Then every job must be divided into its proper elements. Care must be taken to avoid the pitfall of infinitesimal subdivision of elements. Such minuteness can make the timing operation unduly complex, with resultant serious errors in computation and low validity and reliability. Short elements are particularly plaguing if they come in sequence. In some cases it might be advantageous to alternate short and long elements in such a fashion that the probability for accuracy in timing will be greatly increased.

After the job elements have been arranged in sequence, attention must be given to determine whether or not some of these elements are out of their regular sequence. All foreign elements must be identified and must be isolated. Adjustments must be made for legitimate elements missed by the observer or omitted by the operator. In this detailed elemental analysis it is also imperative to distinguish constant and variable elements. Separation of constants and variables facilitates work measurement and provides more accurate analysis. It is also important to set a discreet limit to the number of elements integral to a particular operation. Since the observer must have some knowledge of each element relative to its importance, sequence, etc., too many elements can impair the observer's performance. There are no inflexible rules for determining the workable number of elements for a given situation. Judgment sets these limits.

Sample Size. Common sense should indicate that it is dangerous to make assumptions as to work-cycle length on the basis of a single

timing. Even more questionable are elemental times determined from only one observation. The next step, then, is to obtain additional observations from which an average or representative time can be computed. As was previously mentioned, the most commonly used measures of central tendency are the arithmetic mean and the median. Selection of the specific measure should follow precedents basic to sound statistical technique. For example, if extremely large samples are used, both the mean and the median will tend to be identical. If the sample is relatively small, there is always the possibility that one or more "out-of-line" timings can distort the average. Regardless of which norm, the arithmetic average or the mid-point in the array, is chosen, it must be remembered that the validity and reliability of the observations are contingent upon proper control of working conditions and sampling techniques. While rigid formulas are available for determination of sample size, expediency frequently dictates use of arbitrary limits, such as ten or twenty cycles, for setting the total number of observations. Logic also dictates that in situations where one or more elemental or cycle times are significantly different from the average, such observations ought to be excluded from the sample.

Formulas are also available for measuring the variability of selected averages. One of the best known of these formulas, $\sigma = \sqrt{\Sigma d^2/N}$, measures the standard deviation. The d^2 summation is derived first by subtracting the observed individual elemental time from the average and then squaring each of these individual differences. The symbol N refers to the number of readings of a single element. The important aspect of this application of a basic statistical technique is the availability of an index showing the probability that variance is within certain known bounds. The significance of the 67, 95, and 99 plus percentiles, associated with the plus and minus 1, 2, and 3 standard deviations from the measure of central tendency, has been explained in previous chapters.

As has been stressed in practically every instance where mathematical tools are usable in industry, such tools must never be assumed to give infallible conclusions. Even in the simple stop-watch-timing technique variance in the reflexes of individual time-study operatives affects the accuracy of the recordings. Worker attitudes and variability in working conditions likewise can distort results. The ~~degree of job~~ standardization and the ability to differentiate minute job elements are also significant factors. These are only a few of the numerous deterrents to scientific work measurement.

Emphasis on caution is injected at this point to temper the would-be

efficiency expert since from here on every work-measurement method, despite its stress on objectivity, rests very heavily on individual judgment. Obviously, increased reliance upon judgment means that the probability of error is more than proportionately increased.

Normal, or Standard, Time. When the averages have been properly computed for each element, these averages are then totaled to determine the average cycle time. This summation of elemental times for a given work cycle is frequently termed the base time. It becomes the reasonable and attainable standard which could be expected of every worker on that particular type of job. There is one assumption, however, underlying this conclusion, namely, that the time-study data pertain to the average, or typical, worker. Such an assumption, unfortunately, cannot be made because one of the precepts of sound work-measurement techniques is the insistence that the study be made on the basis of a superior worker's performance. This necessitates making proper allowances, thus adjusting the standard to the level of the typical worker. The procedure by which this is accomplished is known as performance rating, or leveling. The product of performance rating, or leveling, is termed normal, or standard, time. It should be obvious that this figure is simply the average observed time plus the additional time allowance which makes it more feasible for the typical worker to reach the prescribed standards.

The simplest approach to leveling would involve making an estimate of the approximate degree of superiority of the worker being rated over the average worker. Obviously, such estimates are rather tenuous and depend upon the judgment and integrity of the person making the performance-rating adjustments. Generally, rather than rely upon arbitrary estimates, it is preferable to use a factor-degree technique, as summarized in Exhibit 13-2. This method separates four vital characteristics which are generally assumed to be important in influencing performance. For example, if the person being rated happened to put forth far more effort than was usually associated with the type of work in question, then the leveling must include a "plus" allowance. First, it must be decided as to how much above average was this effort expenditure. There are five gradations above average, which is designated by the letter *D*. If the ratee is classified as *A*1 for effort, then the plus allowance is 13 per cent. In some rare instances, the person being rated might put forth less-than-average effort. Thus a "poor" classification of the *F*2 level would mean a minus value of 17 per cent. Each of the other three factors is appraised in similar fashion.

The logic for adding percentages to the allowed time for superior

skill, effort, conditions, and consistency should be obvious. By this addition, more time is permitted for the completion of the given task. Thus the average worker is not demoralized by being forced, despite his inherent limitations, to duplicate the performance of the superior workman. On the other hand, the better man, because of the increase

Exhibit 13-2. Leveling Factors

Skill			Effort		
+0.15	A1	Superskill	+0.13	A1	Excessive
+0.13	A2		+0.12	A2	
+0.11	B1	Excellent	+0.10	B1	Excellent
+0.08	B2		+0.08	B2	
+0.06	C1	Good	+0.05	C1	Good
+0.03	C2		+0.02	C2	
0.00	D	Average	0.00	D	Average
−0.05	E1	Fair	−0.04	E1	Fair
−0.10	E2		−0.08	E2	
−0.16	F1	Poor	−0.12	F1	Poor
−0.22	F2		−0.17	F2	
Conditions			**Consistency**		
+0.06	A	Ideal	+0.04	A	Perfect
+0.04	B	Excellent	+0.03	B	Excellent
+0.02	C	Good	+0.01	C	Good
0.00	D	Average	0.00	D	Average
−0.03	E	Fair	−0.02	E	Fair
−0.07	F	Poor	−0.04	F	Poor

SOURCE: S. M. Lowry, H. B. Maynard, and G. J. Stegemerten, *Time and Motion Study and Formulas for Wage Incentives,* McGraw-Hill Book Company, Inc., New York, 1940, p. 233.

in permissible time, can now complete more tasks and thus earn a bonus.

As a simple example of leveling, assuming that a person whose work was subject to the time study was labeled as *B*1 for skill, *C*1 for effort, *A* for working conditions, and *B* for consistency, the 11 + 5 + 6 + 3 additional points would mean that 20 per cent should be added to base time. Normal time would then equal 120 per cent of base time.

The subjective aspects of leveling should be apparent. Too lenient an appraisal of the four factors can easily mean excessively high leveling factors. While this might initially give the appearance that wages are thus raised proportionately, such reasoning is specious. The excessively high wages resulting from too high a leveling factor can only mean higher production costs, with ultimate yielding to more efficient competitors. Conversely, a leveling factor that is too severe will invariably lead to charges that the enterprise is paying disproportionately low wages.

Allowed, or Task, Time. While normal time represents a far more realistic criterion than does base time, additional adjustments must be made before this time can be accepted as a production standard. In particular, an adjustment must be made for a variety of allowances reflecting legitimate delays and interferences to the production sequence. These allowances are usually grouped under four categories: personal, fatigue, unavoidable, and special. The personal allowances, as can be inferred, vary widely as set by physical factors, custom, or law. The fatigue factor, still relatively unexplored, requires considerable judgment in its conversion into tangible terms. The unavoidable allowances can only be included after reference is made to the unforeseen interferences which have affected production in the recent past. Careful estimates must be made as to the probability that these interferences will recur. The special allowances also require careful judgment. They pertain to adjustments which must be made because of changes in quality of material, size of product, change in tools, etc.

A fifth category, avoidable delay, is generally recognized as affecting operating time. However, avoidable delays cannot be incorporated into standard time. Although realism dictates that production planners be cognizant of these deterrents to efficiency, no allowance can be given the worker who knowingly and willfully impedes the smooth functioning of the organization. In fact, once avoidable delays have been identified and measured, immediate steps should be taken to eliminate such waste.

On the other hand, the first four categories of allowances are made in simple recognition that the ideal is generally tempered by circumstance. The only reason these allowances are not included directly in the computation of base time is their relative infrequency of occurrence. Hence a percentage allowance is generally made on the basis of normal time ascribed to the operation.

In summary, the steps in determining standard times by conventional stop-watch methods include:

1. Applying methods-analysis procedures to the job in question
2. Breaking the job down into its elemental components
3. Deciding upon the proper number and sequence of the elements involved
4. Computing a statistical average time for each element
5. Totaling average elemental times, thereby setting the *base* time
6. Leveling base time to the ability of the average workman exerting average effort under average working conditions (generally called *normal* time)
7. Modifying normal time into *standard* time by adding allowances for unavoidable interferences

TECHNIQUE 2. Statistical Standards

Work Sampling. This is one of the most recent adaptations of fundamental scientific-management techniques to specific industrial situations. In essence, work sampling, or the ratio-delay method, as it is sometimes called, is merely a toned-down application of probability theory. It was first suggested by L. H. C. Tippett in the February, 1935, issue of *The Journal of the Textile Institute Transactions* for application in the British textile industry. Five years later Professor Lee Morrow of New York University introduced the technique and the term ratio-delay to American industry.

Presumably this technique provides a fairly accurate estimate of the ratios of productive to nonproductive times. These broad categories can also be broken down into a great variety of operation elements and specific types of interference to the work cycle. The principle underlying this technique is that random observation of a given job, if done often enough, will give an index of how the individual on that job actually spends his time.

The stress on random observations is extremely important. Noting what occurs at a particular point in time over even a long period or making the observations in a regular pattern can lead to faulty conclusions. For example, if all observations are so spaced that they are made only during lunch or rest periods, it would appear that the worker does nothing but eat and relax while on the job. While there is a remote possibility that such might be the case, sound reasoning tells us that the inference is invalid because randomness is lacking in the sample of observations.

A simple device to ensure randomness is to have the observer walk to the work scene in a pattern so determined that the principles of random selection will be kept intact. This procedure could require that each area to be visited is designated by a number. These numbers

can then be mixed in a random fashion, following which they should be arranged manually in a random number sequence. Even more reliability would result from recourse to specially designed and readily available tables of random numbers.

Whatever scheme is used to ensure randomness in visits to specific work places, it is also imperative that rigid rules be enforced in respect to the manner in which the observations are made. For example, a real or imaginary line can be set, from which location the time analyst always makes his observations. This rigidity is requisite to proper sampling technique. Obviously, the persons whose jobs are being studied should not be able to anticipate the observer's visits. Such knowledge could easily vitiate the device's validity and reliability.

As with all sampling methods, caution must be exercised in respect to proper sample size. This applies not only to this technique but to all methods based on sample data. One favorable feature of the work-sampling approach is the facility with which relatively large samples can be accumulated at relatively low costs. Since the recording of individual observations takes only a fraction of a minute, the number of observations which can economically be made depends largely upon the distances the observer must travel from one work station to the next. This economic limitation upon the sample size must be equated with the proper number of observations as determined statistically. Caution should be exercised, particularly if the

Exhibit 13-3. How Number of Required Observations Varies in Relation to Percentage Occurrence of Element and Accuracy Desired in Work-sampling Results

Percentage occurrence of element	Number of observations required		
	1% accuracy	5% accuracy	10% accuracy
1	3,960,000	158,400	39,600
5	760,000	30,400	7,600
10	360,000	14,400	3,600
20	160,000	6,400	1,600
30	93,330	3,730	930
40	60,000	2,400	600
50	40,000	1,600	400

SOURCE: C. L. Brisley, "Work Sampling," sec. 3, chap. 5, in H. B. Maynard (ed.), *Industrial Engineering Handbook*, McGraw-Hill Book Company, Inc., New York, 1956, p. 3-74.

number of elements is increased significantly and if a high degree of accuracy is demanded. With such stipulations the number of observations required could reach fantastic proportions, making this type of analysis unworkable. For example, the preceding table shows how the number of required observations varies in relation to the percentage occurrence of element and accuracy desired.

Thus if the element in question occurs only 1 per cent of the time and a 1 per cent level of accuracy is deemed necessary, the number of observations reaches a fantastic figure. This 1 per cent level of accuracy, incidentally, means that on the basis of the observations, there is only 1 chance in 100 that the percentage occurrence of the element deviates from the true percentage occurrence. Such stringent prescriptions are rarely necessary in any but exceptional industrial situations.

Since this technique is a statistical device, there are many statistical measures which can be applied. For example, there is the formula

$$N = \frac{4(1-p)}{y^2P}$$

derived from a modification of the familiar formula for the standard

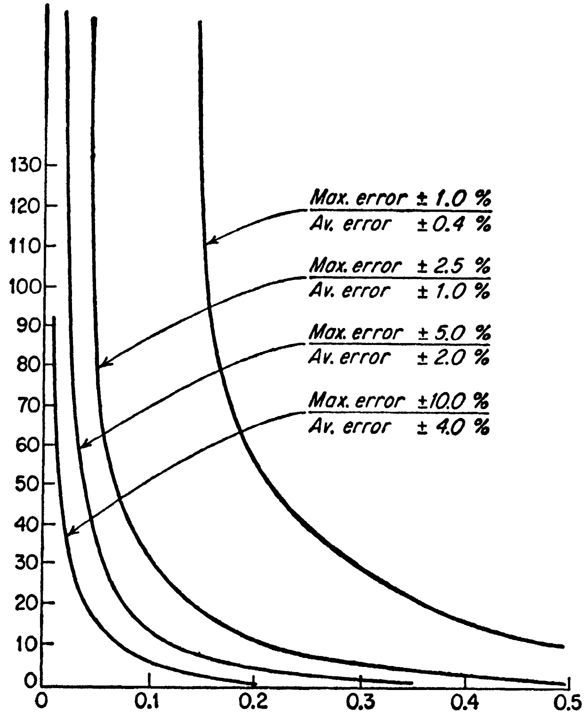
$$\sigma = \sqrt{\frac{p(1-p)}{N}}$$

error of the percentage. N refers to the number of observations; p equals the percentage occurrence, in decimal terms, of the element in question; and y is the accuracy desired, in decimals.

One very convenient way to show the interrelationship of maximum error, length of element, and number of observations is shown in Exhibit 13-4. This type of presentation facilitates determining the approximate number of cycles that must be timed to get results of specified degrees of validity and reliability. In this particular chart, a simple inspection would readily show that for an element of 0.15 minute duration only one or two cycles need be timed if the maximum margin of error is set at ±10.0%, with average error at ±4.0%. However, if these tolerances were changed to ±1.0 and ±0.4%, respectively, then the sample size must be increased to about 120 observations.

In the simplest form of work-sampling analysis, three categories of information are generally recorded. In addition to productive or cycle time, these include necessary delays and unnecessary interferences.

Exhibit 13-4. Graph for Determining Sample Size in Time Study



BASIS: Standard deviation $\sigma = 0.008$ minute, variability due to use of decimal-minute stop watch (snap-back or continuous)

Max. error = error in per cent which will be exceeded, in the long run, only 5 per cent of the time

Av. error = average error, per cent

SOURCE: *Journal of Industrial Engineering,* February, 1953, official publication of the American Institute of Industrial Engineers, Inc., Columbus, Ohio.

Thus, for example, in a typical case in which 250 observations were made, the distribution might have been as follows:

Element	Number of observations	Percentage of total time
Production time	180	72
Necessary delays	30	12
Unnecessary delays	40	16
Total	250	100

Obviously, this type of work-sampling illustration gives virtually no information as to specific production elements nor any hint as to the reasons for delay. These studies can, however, be made as detailed as deemed necessary. For example, if a work-sampling study had been made of the operation studied by the continuous stop-watch-timing method in Exhibit 13-1, the results might have been somewhat similar to the data listed in Exhibit 13-5, which follows. Studies of 50 and 200 observations are depicted to contrast the greater degree of accuracy as the sample size increases.

A casual inspection of column 3 shows some variance between the stop-watch-timing technique (Exhibit 13-1) and the results obtained from work sampling. The variance is particularly noticeable in the elements of relatively short duration. Theoretically, there is far less

Exhibit 13-5

Activity	(1) Number of observations		(2) Per cent of sample	(3) Per cent of normal operating cycle	
	$N = 50$	$N = 200$	$N = 200$	$N = 50$	$N = 200$
Normal operating cycle					
Adjust lever	0	4	2.0	4.0	4.2
Reach for material	1	5	2.5	5.0	5.8
Position material	3	14	7.0	14.0	13.8
Operate machine	7	25	12.5	25.0	25.1
Release lever	2	6	3.0	6.0	6.4
Remove product	3	11	5.5	11.0	11.2
Inspect product	5	26	13.0	26.0	26.1
Store product	2	9	4.5	9.0	7.4
Total				100.0	100.0
Unavoidable delays					
Rest periods	3	15	7.5		
Material-flow delay	2	7	3.5		
Machine adjustment	6	17	8.5		
Machine breakdown	0	4	2.0		
Order giving and taking	6	17	8.5		
Avoidable delays					
Idle conversation	9	24	12.0		
Just plain idle	1	16	8.0		
Total	50	200	100.0		

probability of error, assuming average diligence, when an element constitutes 20 per cent or more of the total operating-cycle elapsed time. The logic for these inferences has been shown in the explanation of the relationship of sample size, accuracy required, and incidence of error.

Assuming that all the statistical cautions are observed, the technique is still somewhat limited in so far as inefficient motions can easily escape detection. In particular, there is no assurance that the persons being observed, although actually engaged in productive as versus nonproductive endeavor, are not attempting a work slowdown by pacing themselves. Considerable experience, skill, and judgment are needed by the observers before they can properly determine the effort level of specific operatives. Another serious objection is the difficulty in preventing infrequent activities from biasing the conclusions. If the study happens to be made during the period when the infrequent activity is being performed, it is reasonable to assume that, lacking proper adjustment, the work-sampling results can be misleading.

As a sort of counterbalance to the weaknesses of this technique, it must be pointed out that unless extreme precision in time measurement is mandatory, this technique usually provides an acceptable level of accuracy. To get these results, there is no need for highly trained observers. The statistical aspects, however, will necessitate employing an analyst with at least more than a rudimentary knowledge of statistical methodology. The gathering of pertinent data tends to take less time and to cost less. No elaborate equipment is needed. There is less danger that the time study will cause interferences with the normal production process. Finally, the study can be made over a long period of time and at the convenience of the observers and analysts.

TECHNIQUE 3. Synthesized Standards

Both stop-watch standards and statistical standards in time-output analysis can entail considerable costs, particularly if the work cycle is subject to frequent modification. Then too, these techniques have serious limitations for use with new or proposed jobs. Obviously, time standards for new jobs tend to be arbitrary. In most instances the analyst estimates what should constitute proper time allowances for the new job on the basis of time standards currently in force for comparable jobs. Such standards estimated by a relatively crude comparison can be accepted only with serious limitation.

Although therbligs, as standardized elements of motion or performance, have been accepted for nearly half a century, the

idea of setting standard times for therbligs did not gain widespread acceptance until this decade. The major drawback to the use of standard times for standardized elements of motion was the almost infinite variation in the working conditions. Thus a "reach" over a distance of 6 inches can be assumed to be different from a reach extending 2 feet. Likewise, a vertical reach is quite dissimilar from a horizontal reach. Deeper investigation would indicate that every therblig is subject to modification by a vast number of circumstances. These variables significantly affect the legitimate setting of time standards.

While this variability can be presumed to present serious limitations, recent studies have proved that they are not insurmountable. To overcome them, at least two basic premises must be established: first, that only a few of the variables have a significant influence upon performance; second, that by concentrating upon the most important of these variables, average times can be established for the elements of motion adjusted to these variables. For example, if x is the accepted average time for a 6-inch horizontal reach, then $1.2x$ might be the standard for a 2-foot horizontal reach, while the 2-foot vertical reach might be allowed $1.4x$. This simple example merely shows the logic underlying this adjusting of time values because of variable influences. In effect, then, the standard times assume the character of a range of values. Nevertheless, for any single value of the variable there is a set time allowance. When these time standards have been adequately corroborated for all the elements involved, the values can be viewed as synthesized times. More recently the term *predetermined elemental times* has been applied to a steadily increasing number of variants of this technique.

Despite differences in procedure and nomenclature, effective application of predetermined-elemental-time techniques in every instance depends intimately upon:

1. Precision in isolation of therbligs
2. Identification of internal forces immediately modifying the specific therbligs
3. Recognition of external forces injecting the equivalent of new additional variable factors

As a simple illustration, the grasp therblig is normally easy to identify. However, it is commonly understood that there are several distinct types of grasp. Mundel lists:[2]

[2] Marvin Mundel, "Motion and Time Study," sec. 5, in W. G. Ireson and E. L. Grant (eds.), *Handbook of Industrial Engineering and Management,* Prentice-Hall, Inc., Englewood Cliffs, N.J., 1955, p. 373.

1. Contact: control gained by mere contact.

2. Contact pinch: control gained by contact with one or more fingers sliding the object into a position so that the thumb could oppose them.

3. Pinch: control gained by maneuvering the hand so that the thumb and one or more fingers come into opposition on the object.

4. Wrap: control gained by fingers and palm coming into opposition on object.

Mundel also refers[3] to the significance of external factors in his reference to the time for a therblig as being a function of:

a. Distance.
b. Complexity of action.
c. Amount of body involved.
d. Bimanualness involved.
e. Whether the use of the feet accompanies the action.
f. The eye-hand coordination required.
g. The sensory requirements.
h. The weight or resistance involved.
i. The preceding and following therbligs as well as the context of the whole pattern of the task.
j. The direction of movement.
k. The place of the therblig in a motion pattern.
l. Possible interactions of two variables.
m. Several other variables as yet unidentified. (Even when the effects of variables "*a*" through "*k*" are extracted, considerable variations in observed data still exists.)

It should be evident by now that predetermined or synthesized elemental time plans can vary widely not only as to procedure and terminology but also in the degree to which the therblig conditioning forces are considered. Presumably an analysis of three of the better-known synthesized elemental time techniques, time formulas, methods-time measurement, and Work-Factor System, should be adequate to illustrate this management tool.

TECHNIQUE 3A. Time Formulas

A formula is simply an expression in algebraic or symbolic form of a specific relationship among constant and variable factors affecting a situation. To the uninitiated, the algebraic presentation can be both unintelligible and disconcerting. Formulas are, in effect, compressed ideas set up in a codified fashion. These compressed and coded messages are meaningless without the ability to translate the symbols into their descriptive form. However, to the technically competent, formu-

[3] *Ibid.*, p. 381.

las are probably the fastest, cheapest, and most convenient way of expressing ideas.

Reference has been made in one of the earlier chapters to Taylor's pioneering venture in converting into formulas his studies of methods and times involved in the effective utilization of high-speed cutting tools. Taylor and his associates, after many years of experimenting with various metals, with a host of tool designs, and with innumerable methods, created his classic 11-variable formula. Many other scientific-management pioneers have contributed additional exploratory works. The entire gamut of contributions in this sphere reflects the recognition of the need for, and even the urgency for, replacing guesswork with scientifically deduced estimates and standards. This endeavor is merely a manifestation of the importance attached to quantification for more effective scientific management.

Among the more impelling reasons which led to more precise work measurement, to better standards, and thence to the expression of elapsed time in formula fashion was the rapid recognition, by methods-and-time analysts, that it was physically and economically impossible to perform valid time studies on each and every industrial operation. This was particularly true where operations were not highly repetitive or where frequent changes in product styles necessitated equally frequent modifications in the work cycle and elemental times. Time-study men have long recognized the value of setting up "synthetic" times, that is, a composite of elemental times considered as averages for the specific elements concerned. This synthesis of commonly accepted average elemental times means that costly individual time studies for each operation are unnecessary. However, it should also be evident that in this acceptance of standardized elemental times certain assumptions prevail. The appraisal and identification of every element must be exact. Constant and variable elements must be carefully segregated. In particular, variables must be measured with great precision. Finally, the result is subject to all the limitations involved in the mathematical measurement of physical phenomena affected by numerous human factors.

The differentiation of constant and variable elements demands clear and concise definitions. The selection of a value for a given constant usually entails the exercise of good judgment. Invariably there is a range in these values. It is at this point that the analyst must discern and reject atypical times which would otherwise bias the calculation of the average. In some cases the "constants" remain rigid over only a narrow range of activity. On the other hand, sometimes the variance in the opposite category is so slight that the "variable" approximates

a constant. Good judgment is essential to make the best decisions in such differentiating. Then too, the number of factors can reach such proportions that individual designation in a formula would result in a most unwieldy expression. It is at this point that the properly designated constants are lumped together in a single value, thus simplifying the symbolic presentation.

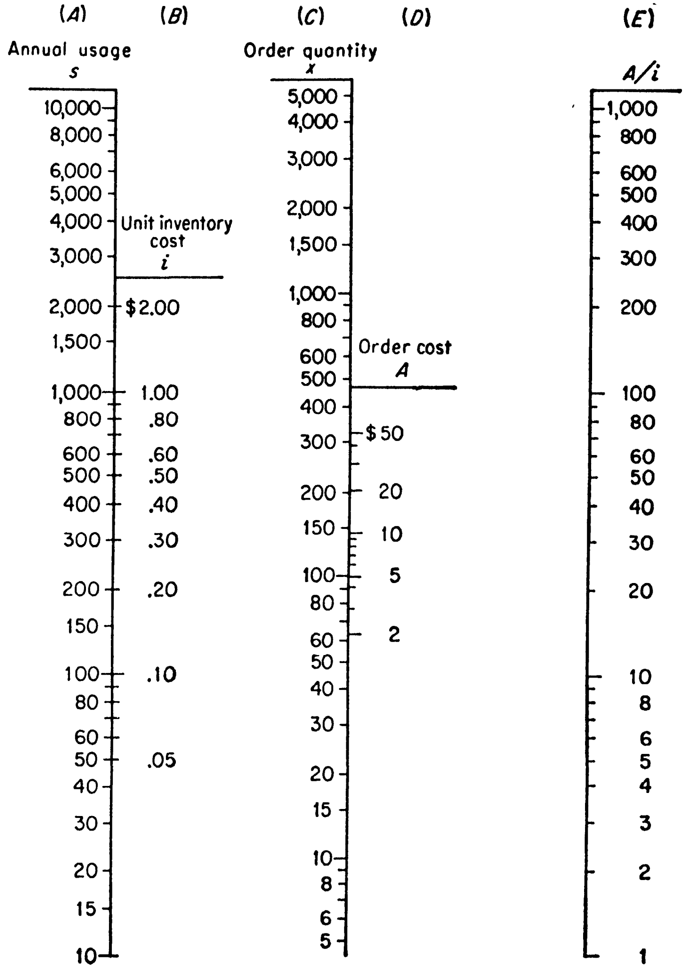
Variables present considerably more difficulty in segregation, appraisal, and exact measurement. Analytical ability and sound technical grooming are paramount in this phase. The "practical man," the novice, and the "generalist" invariably prove their inadequacy at this point. It is here that the experimental procedure must yield information as to the relationships among two or more factors. These relationships can best be expressed in tabular or curve form. Tables are much easier to use, especially for the less proficient analysts. There is less opportunity to make errors since the relationships are clearly expressed. However, tables can be bulky. The need for interpolation can also be handicapping.

Curves, on the other hand, give a graphic presentation which conveys almost immediately the gist of the relationship. More precise measurement can then be resorted to if detailed information is needed. The method by which straight-line relationships should be plotted will be demonstrated in technique 3 of Chapter 17 on Job Evaluation. Using the straight-line formula $y_c = a + bx$, the relationship can readily be shown graphically. Thus, if one variable is given, the corresponding value of the second variable can be estimated with considerable assurance of accuracy.

The relationship between two variables can be plotted on rectilinear coordinate paper. However, if the relationship is not of the straight-line type, it seems preferable to plot the data on logarithmic coordinates using log-log paper. By this measure curvilinear expressions can sometimes be depicted in the manner of the straight-line relationships. For all practical purposes it is generally considered preferable to leave the curve in its graphic form rather than to show the relationship algebraically.

One of the most satisfactory methods for expressing the effect of two or more variables upon a specific operation is to translate the relationship as shown in tables, graphs, or equations into nomograms. By this means two or more variable values can be divided or multiplied by a very simple procedure. An example of a nomogram is shown in Exhibit 13-6. All that is needed once the chart has been constructed is to pin-point the variable values on the respective scales. For example, if annual requirements of a particular item totaled

Exhibit 13-6. Ordering Nomogram.



SOURCE: J. F. Magee, *Production Planning and Inventory Control,* McGraw-Hill Book Company, Inc., New York, 1958, p. 54.

10,000, unit costs averaged $4, annual carrying charges amounted to 25 per cent of unit cost, and preparation charges were $50 per order, the procedure would be as follows. Using columns *B* and *D,* connect with a straight line the $1 point (25 per cent of $4) on scale *B* with the $50 point on scale *D*. Extend this line to where it will intersect scale *E*. This intersection will occur at approximately the 50 mark. Next join the 50 on scale *E* with the 10,000 point on scale *A*. This line

will cross scale C at about the 1,000 mark. This is the economic-ordering quantity. The solution, as given by the nomogram, can be easily corroborated by using the economic-lot-size formula described in technique 3, Chapter 4. Given specific values for a set of variables and having calculated the interrelationships among these variables, nomograms can be constructed for practically any arithmetic or algebraic problem.

The formula technique can be used with stop-watch data or with predetermined motion-time data. Although in actual practice there are some important differences between these basic techniques, it seems judicious, at this point, to emphasize only the highlights. After all the elements are listed, the analyst should synthesize by first combining all constants which are expressed in terms of the same unit. Then related variables should be added together in their respective curves or tables.

The final step in the formula expression is taken when the combined constants and variables are added together. This formula, together with all pertinent information, is then generally condensed in a comprehensive formula report. The components of this type of report include:

Part	What	
Operation	How	
Work station	Where	Summary
Allowed time	Final result	
Application	When	
Computation sheet	Method of use	
Analysis	Background	
Procedure	Technical facts	
Time studies	Source of data	
Table of elements	Summary of basic data	Body
Synthesis	Development of data	
Inspection, Payment	Conditions	
Approval		
Element analysis		Appendix

SOURCE: S. M. Lowry, H. B. Maynard, and G. J. Stegemerten, *Time and Motion Study and Formulas for Wage Incentives*, McGraw-Hill Book Company, Inc., New York, 1940.

The section labeled "allowed time" is the actual formula expressed in tabular form and very readily convertible into graphic form. In those few cases where algebraic expression is deemed necessary, the data can be converted into an equation. For example, in developing

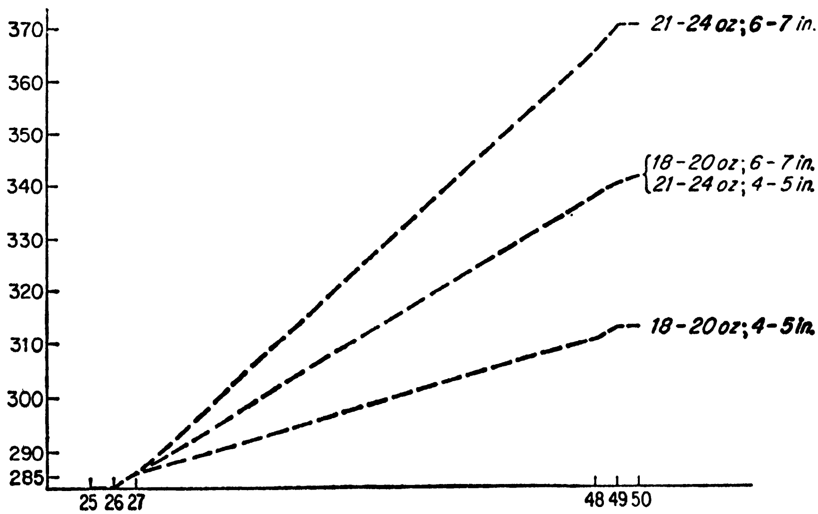
Exhibit 13-7

Length of panel, inches	Time for turning leather bottom			
	18–20 oz, 4–5 in. bottom width	18–20 oz, 6–7 in. bottom width	21–24 oz, 4–5 in. bottom width	21–24 oz, 6–7 in. bottom width
25	0.00283	0.00283		0.00283
26	0.00283	0.00283		0.00283
27	0.00286	0.00286		0.00286
48	0.00311	0.00339		0.00366
49	0.00314	0.00341		0.00371
50	0.00314	0.00342		0.00371

SOURCE: L. B. Grella, "Time Formulas," sec. 3, chap. 10, in H. B. Maynard (ed.), *Industrial Engineering Handbook,* McGraw-Hill Book Company, Inc., New York, 1956, pp. 3–167.

a formula for turning leather bottoms of door panels for doors 25 to 50 inches in length, Grella develops it as a table (Exhibit 13-7). This formula could also be presented graphically as shown in Exhibit 13-8. In this case the variable designated as ounces and bottom width

Exhibit 13-8. Time for Turning Leather Bottom



SOURCE: L. B. Grella, "Time Formulas," sec. 3, Chap. 10, in H. B. Maynard (ed.), *Industrial Engineering Handbook,* McGraw-Hill Book Company, Inc., New York, 1956, pp. 166–172.

in inches is not adequate from an arithmetic-sequence point of view. The three curves shown in the figure indicate a significant variance as the length of panel increases toward the maximum size listed. At the lower dimensions of length of panel, the second variable, ounces and inches of bottom width, has practically no effect upon the standard time.

The figures shown in the table were, in this case, derived from methods-time-measurement tables. Since this technique will be explained in the following section, emphasis at this point will be given only to the computational methods pertinent to this case. Exhibit 13-9

Exhibit 13-9

Symbol	Table of elements	
	Description	Allowed time
A	Pick up panel from conveyor	0.00076
B	Turn leather bottom	Table B
C	Smooth leather on back of panel	Table C
D	Turn leather sides and corner	0.00071
E	Dispose of panel on conveyor	0.00054
F	Get petroleum jelly from jar	0.00114
G	Rub petroleum jelly from back of hands onto palm of hands	0.00053

SOURCE: L. B. Grella, "Time Formulas," sec. 3, chap. 10, in H. B. Maynard (ed.), *Industrial Engineering Handbook,* McGraw-Hill Book Company, Inc., New York, 1956, pp. 3–169.

and its explanation, also borrowed from Grella's presentation, show the procedure involved in the synthesis phase.

Synthesis. Constant per panel:

$$A + D + E = 0.00076 + 0.00071 + 0.00054 = 0.00201$$

Constant for each 400 panels:

$$F = 0.00114$$

Constant for each four panels:

$$G = 0.00053$$

Elements B and C are variables whose values must be determined after all the conditioning circumstances have been properly assayed and weighted. For example, in this case, element B, turning the leather

bottom, is presumed to be dependent upon the number of pulls involved, which in turn are the result of:

1. The weight of the leather
2. The width of the leather measured from molding or sew line to the bottom of the panel
3. The length of the door panel

The effect of each of these influencing factors upon the standard allowed time must be measured. Individual tables must be constructed from basic methods-time-measurement data for this measuring process. The final formula is simply a summation of the seven elements, as indicated by symbols *A, B, C, D, E, F,* and *G* in Exhibit 13-9.

$$\text{Elements } A + D + E = 0.00076 + 0.00071 + 0.00054 = 0.00201$$

$$\text{Element } F = \frac{0.00114}{400} = 0.000003$$

$$\text{Element } G = \frac{0.00053}{4} = 0.000132$$

Elements *B* and *C* since they are variable, must be obtained from the specially computed tables. In this particular situation, as an example, for a 50-inch panel with 24-ounce leather 7 inches wide, the Table *B* value is given as 0.00104 and the Table *C* value is 0.00053. The sum of the seven elements is

$$0.00201 + 0.000003 + 0.000132 + 0.00104 + 0.00053 = 0.003715$$

This figure is shown in Exhibit 13-7.

Although this time-formula presentation has touched only upon the bare methodological essentials, it should be kept in mind that, like all formulas, this is a time- and cost-saving tool. It has considerable advantage over the basic stop-watch timing of entire operations. On the other hand, it demands in the analyst a technical competency of a higher order than that found in the typical time-study man.

TECHNIQUE 3B. Methods-Time Measurement (MTM)

Although this version of predetermined elemental timing was only recently made public, its almost immediate acceptance seems to indicate that this is the sort of standard performance-rating device which scientific industrial managers have long been seeking. Basically, the system can be synthesized to a concise cataloguing of work motions and a refined scale of predetermined time values for each. These fundamental values have been condensed into compact card forms, shown in Exhibits 13-10 to 13-13.

Exhibit 13-10. Methods-Time-Measurement Application Data

SIMPLIFIED DATA*

Hand and Arm Motions			Body, Leg, and Eye Motions	
Reach or Move		*TMU*		*TMU*
1″		2	Simple foot motion	10
2″		4	Foot motion with pressure	20
3″ to 12″4 + length of motion			Leg motion	10
over 12″3 + length of motion				
(For Type 2 Reaches and Moves			Sidestep, case 1	20
use length of motion only)			Sidestep, case 2	40
Position				
Fit	*Symmetrical*	*Other*	Turn body, case 1	20
Loose	10	15	Turn body, case 2	45
Close	20	25		
Exact	50	55	Eye time	10
Turn-apply pressure				
Turn		6	Bend, stoop or kneel on one	
Apply pressure		20	knee	35
Grasp			Arise	35
Simple		2		
Regrasp or transfer		6	Kneel on both knees	80
Complex		10	Arise	90
Disengage				
Loose		5	Sit	40
Close		10	Stand	50
Exact		30		
			Walk per pace	17
1 TMU = 0.00001 hour				
= 0.0006 minute				
= 0.036 second				

* All times include 15 per cent allowance.

SOURCE: Methods Engineering Council, Bridgeport, Conn., and MTM Association for Standards and Research, Ann Arbor, Mich.

In essence, the MTM method seems to be extremely simple. It is, however, the culmination of considerable research and application. The concept of using predetermined elemental times for basic-motion components was first developed by Frank Gilbreth. Although his therbligs, process charts, micromotion studies, and related contributions were quickly accepted, very little public support was given to his thesis that standard times could be determined for standard elemental motions. About twenty years ago several performance-rating systems were introduced, among them A. B. Segur's. However, Segur's method was kept a professional secret since he insisted, by contract, that his clients should not divulge his methods. Even if his contribu-

Exhibit 13-11

TABLE I—REACH—*R*

Distance moved, inches	Time, TMU				Hand in motion		Case and description
	A	*B*	C or *D*	*E*	*A*	*B*	
¾ or less	2.0	2.0	2.0	2.0	1.6	1.6	
1	2.5	2.5	3.6	2.4	2.3	2.3	*A* Reach to object in fixed location, or to object in other hand or on which other hand rests.
2	4.0	4.0	5.9	3.8	3.5	2.7	
3	5.3	5.3	7.3	5.3	4.5	3.6	
4	6.1	6.4	8.4	6.8	4.9	4.3	
5	6.5	7.8	9.4	7.4	5.3	5.0	*B* Reach to single object in location which may vary slightly from cycle to cycle.
6	7.0	8.6	10.1	8.0	5.7	5.7	
7	7.4	9.3	10.8	8.7	6.1	6.5	
8	7.9	10.1	11.5	9.3	6.5	7.2	
9	8.3	10.8	12.2	9.9	6.9	7.9	C Reach to object jumbled with other objects in a group so that search and select occur.
10	8.7	11.5	12.9	10.5	7.3	8.6	
12	9.6	12.9	14.2	11.8	8.1	10.1	
14	10.5	14.4	15.6	13.0	8.9	11.5	
16	11.4	15.8	17.0	14.2	9.7	12.9	
18	12.3	17.2	18.4	15.5	10.5	14.4	*D* Reach to a very small object or where accurate grasp is required.
20	13.1	18.6	19.8	16.7	11.3	15.8	
22	14.0	20.1	21.2	18.0	12.1	17.3	
24	14.9	21.5	22.5	19.2	12.9	18.8	
26	15.8	22.9	23.9	20.4	13.7	20.2	*E* Reach to indefinite location to get hand in position for body balance or next motion or out of way.
28	16.7	24.4	25.3	21.7	14.5	21.7	
30	17.5	25.8	26.7	22.9	15.3	23.2	

TABLE II—MOVE—M

Distance moved, inches	Time, TMU				Wt. allowance			Case and description
	A	B	C	Hand in motion B	Wt. (lb) up to	Factor	Constant TMU	
¾ or less	2.0	2.0	2.0	1.7	2.5	1.00	0	
1	2.5	2.9	3.4	2.3	7.5	1.06	2.2	A Move object to other hand or against stop.
2	3.6	4.6	5.2	2.9	12.5	1.11	3.9	
3	4.9	5.7	6.7	3.6	17.5	1.17	5.6	
4	6.1	6.9	8.0	4.3	22.5	1.22	7.4	B Move object to approximate or indefinite location.
5	7.3	8.0	9.2	5.0	27.5	1.28	9.1	
6	8.1	8.9	10.3	5.7	32.5	1.33	10.8	
7	8.9	9.7	11.1	6.5	37.5	1.39	12.5	
8	9.7	10.6	11.8	7.2	42.5	1.44	14.3	C Move object to exact location.
9	10.5	11.5	12.7	7.9	47.5	1.50	16.0	
10	11.3	12.2	13.5	8.6				
12	12.9	13.4	15.2	10.0				
14	14.4	14.6	16.9	11.4				
16	16.0	15.8	18.7	12.8				
18	17.6	17.0	20.4	14.2				
20	19.2	18.2	22.1	15.6				
22	20.8	19.4	23.8	17.0				
24	22.4	20.6	25.5	18.4				
26	24.0	21.8	27.3	19.8				
28	25.5	23.1	29.0	21.2				
30	27.1	24.3	30.7	22.7				

TABLE III—TURN AND APPLY PRESSURE—T AND AP

Weight, lb	Time, TMU, for degrees turned										
	30°	45°	60°	75°	90°	105°	120°	135°	150°	165°	180°
Small— 0–2	2.8	3.5	4.1	4.8	5.4	6.1	6.8	7.4	8.1	8.7	9.4
Medium—2.1–10	4.4	5.5	6.5	7.5	8.5	9.6	10.6	11.6	12.7	13.7	14.8
Large— 10.1–35	8.4	10.5	12.3	14.4	16.2	18.3	20.4	22.2	24.3	26.1	28.2

Apply pressure, Case 1—16.2 TMU. Apply pressure, Case 2—10.6 TMU.

SOURCE: Methods Engineering Council, Bridgeport, Conn., and MTM Association for Standards and Research, Ann Arbor, Mich.

tions were original and worthwhile, the seal of secrecy, while ensuring monopolistic control and higher charges, resulted in Segur's work having little, if any, value in the advancement of scientific management.

A number of corporations experimenting in this sphere also devised custom-made systems suited to their particular needs. Westinghouse Electric Corporation and Radio Corporation of America engineers

Exhibit 13-12

TABLE IV—GRASP—G

Case	Leveled time, TMU	Description
1A	1.7	*Pickup grasp*—Small, medium or large object by itself, easily grasped.
1B	3.5	Very small object or object lying close against a flat surface.
1C1	7.3	Interference with grasp on bottom and one side of nearly cylindrical object. Diameter larger than ½″.
1C2	8.7	Interference with grasp on bottom and one side of nearly cylindrical object. Diameter ¼ to ½″.
1C3	10.8	Interference with grasp on bottom and one side of nearly cylindrical object. Diameter less than ¼″.
2	5.6	*Regrasp*
3	5.6	*Transfer grasp*
4A	7.3	Object jumbled with other objects so search and select occur. Larger than 1″ × 1″ × 1″.
4B	9.1	Object jumbled with other objects so search and select occur. ¼″ × ¼″ × ⅛″ to 1″ × 1″ × 1″.
4C	12.9	Object jumbled with other objects so search and select occur. Smaller than ¼″ × ¼″ × ⅛″.
5	0	Contact, sliding, or hook grasp.

TABLE V—POSITION *—*P*

Handling		Class of fit	Symmetry		
			S	SS	NS
Easy to handle	1—Loose	No pressure required	5.6	9.1	10.4
	2—Close	Light pressure required	16.2	19.7	21.0
	3—Exact	Heavy pressure required	43.0	46.5	47.8
Difficult to handle	1—Loose	No pressure required	11.2	14.7	16.0
	2—Close	Light pressure required	21.8	25.3	26.6
	3—Exact	Heavy pressure required	48.6	52.1	53.4

* Distance moved to engage—1″ or less.

TABLE VI—RELEASE—*RL*

Case	Leveled time, TMU	Description
1	1.7	Normal release performed by opening fingers as independent motion
2	0	Contact release

TABLE VII—DISENGAGE—*D*

Easy to handle	Difficult to handle	Class of fit
4.0	5.7	1—Loose—Very slight effort, blends with subsequent move
7.5	11.8	2—Close—Normal effort, slight recoil
22.9	34.7	3—Tight—Considerable effort, hand recoils markedly

TABLE VIII—EYE TRAVEL TIME AND EYE FOCUS—*ET* AND *EF*

$$\text{Eye travel time} = 15.2 \times \frac{T}{D}\ \text{TMU}$$

where T = distance between points from and to which eye travels
D = perpendicular distance from eye to line of travel T,
with a maximum value of 20 TMU
Eye focus time = 7.3 TMU

SOURCE: Methods Engineering Council, Bridgeport, Conn., and MTM Association for Standards and Research, Ann Arbor, Mich.

were particularly successful in their ventures. In addition, there were numerous compilations of standard data geared to specific jobs.

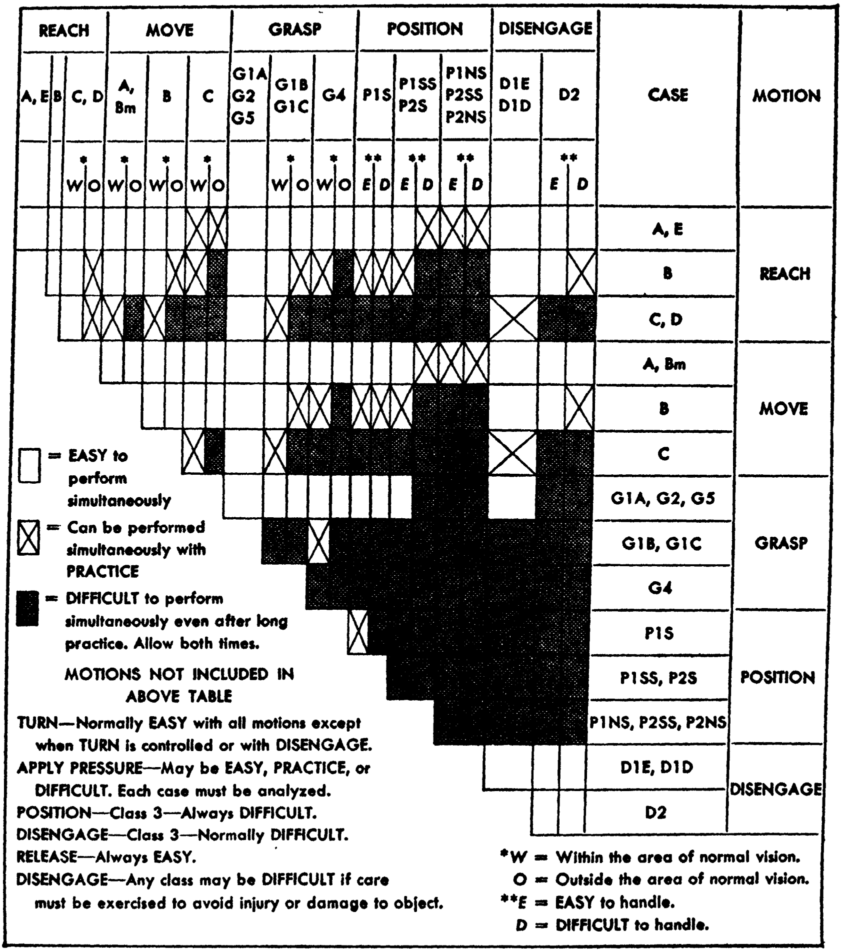
The developers of MTM, Harold B. Maynard, G. J. Stegemerten, and John L. Schwab, were initially instrumental in refining the Westinghouse Electric Corporation's system. Later these three, operating as the Methods Engineering Council, industrial management and engineering consultants, devised the new methods-time measurement. The founders, prior to publicizing their work, subjected their theories and findings to intensive experimentation. The tested and corroborated times were then made public property by the technique's dis-

Exhibit 13-13

TABLE IX—BODY, LEG AND FOOT MOTIONS

Description	Symbol	Distance	Time, TMU
Foot motion—Hinged at ankle	FM	Up to 4 inches	8.5
With heavy pressure	FMP		19.1
Leg or foreleg motion	LM—	Up to 6 inches	7.1
		Each add'l. inch	1.2
Sidestep			
Case 1—Complete when leading leg contacts floor	SS-C1	Less than 12 inches	Use Reach or Move time
		12 inches	17.0
		Each add'l. inch	.6
Case 2—Lagging leg must contact floor before next motion can be made	SS-C2	12 inches	34.1
		Each add'l. inch	1.1
Bend, stoop, or kneel on one knee	B, S, KOK		29.0
Arise	AB, AS, AKOK		31.9
Kneel on floor—both knees	KBK		69.4
Arise	AKBK		76.7
Sit	SIT		34.7
Stand from sitting position	STD		43.4
Turn body 45 to 90 degrees			
Case 1—Complete when leading leg contacts floor	TBC1		18.6
Case 2—Lagging leg must contact floor before next motion can be made	TBC2		37.2
Walk	W-FT.	Per foot	5.3
Walk	W-P	Per pace	15.0

TABLE X—SIMULTANEOUS MOTIONS



SOURCE: Methods Engineering Council, Bridgeport, Conn.

coverers through several publications, including a book, *Methods-Time Measurement*.[4]

While there is an identity as to basic precepts in all predetermined-elemental-time techniques, MTM is distinguishable in a number of respects. By definition it "is a procedure which analyzes any manual operation or method into the basic motions required to perform it and assigns to each motion a predetermined time standard which is determined by the nature of the motion and the conditions under which it is made."[5] The technique uses an easily identifiable basic time, termed a TMU, that is, a time-measurement unit, equaling 0.00001 hour, 0.0006 minute, or 0.036 second. The basic times were initially recorded from motion pictures taken on a 16mm film. A film frame, measured at $\frac{1}{16}$ of a second, provides timing five times as fast as the smallest stop-watch reading.

MTM, in its designation of basic elements, adheres closely to the therblig system. There are 19 basic MTM elements: 8 manual, 9 pedal and trunk, and 2 ocular movements. The time data for these 19 elements are set in 10 compact tables, with times for various classifications of movements expressed in TMUs. These times are postulated as leveled or normal, with no allowances for various needs, delays, or fatigue.

One major advantage of the MTM method is the facility with which novices can acquaint themselves with the principles and procedure by first mastering the simplified version. This less complex modification, despite its simplicity, still gives results which are only about 5 per cent less accurate than the detailed approach. This simplified version is also extremely useful in situations where it is not imperative to have an extremely high degree of accuracy in the setting of the standard times.

Exhibit 13-10 contains all the data needed for application of the simplified MTM procedure. For example, consider a simple work cycle involving:

1. Reach 14 inches for part
2. Simple grasp on part
3. Move part 10 inches
4. Position part, exactly and symmetrically
5. Apply pressure
6. Disengage (close)

Reference to Exhibit 13-10 indicates that a reach of 14 inches requires 17 TMU. A close grasp on the part takes 2 TMU. Moving

[4] S. M. Lowry, H. B. Maynard, and G. J. Stegemerten, *Methods-Time Measurement*, McGraw-Hill Book Company, Inc., New York, 1948.

[5] *Ibid.*, p. 12.

the part 10 inches is a 14-TMU action. The other three elements take 50, 20, and 10 TMU, respectively. Thus 17 + 2 + 10 + 14 + 50 +20 + 10 = 123 TMU. In this case, since the simplified data table was used, a 15 per cent allowance has already been included. The 123 TMU, then, constitutes the standard allowed time for this specific cycle.

The same basic procedure is used for the technique proper except that the data are considerably more detailed. This should be obvious from an inspection of Exhibits 13-11, 13-12, and 13-13. For example, in addition to a more exact definition of the specific motions in terms of "cases," or classifications, distance, weight, angle of action, etc., inject weighting factors. The element of reaching, shown in Exhibit 13-11, is subdivided into five cases, each of which is described in summary fashion. Additional detailed definitions for each case and for even more refined subdivisions are provided in supplementary forms. Experimentation has shown that next to the "degree" of reach, distance is the most important variable. Hence the column "distance moved, inches" is necessary for accurate analysis. The leveled time in TMUs is then determined by (1) deciding upon the particular case to which the specific reaching motion belongs, (2) measuring the distance involved. If the action consisted in reaching 28 inches for an object in a group, then this element would be coded as R28C. Checking horizontally across the "28-inch" line and vertically down the column designated *C* or *D*, a leveled time of 25.3 TMU is noted. If the action pertained to the same case but involved a distance of only 3 inches, the coded motion R3C would have a value of only 7.3 TMU.

Similarly, every other basic element must first be defined, then properly coded, and finally assigned its proper time. Some of the tables include factors for weighting important variables. The last two columns in Table 11 refer to the multiplier by which adjustments are made for variance in weight of objects moved.

Although the tables of application data for detailed MTM study are included in this section, extreme caution is advisable to restrain the neophyte time analyst from too hasty a plunge into this technique. The actual computing of basic elemental times is probably the easiest part of the procedure. The important functions of the scientific time analyst, as has already been stated, revolve about his ability to use his technical knowledge discreetly and to use sound judgment in making the countless multitude of seemingly unimportant decisions relevant to the basic elements of motion.

While MTM has been steadily gaining in popularity, its proponents are quick to point out that the technique cannot be properly applied

to all spheres of industry. The founders of the technique themselves hasten to stress that MTM has serious limitations when used in:

1. Machine-paced operations
2. Process-controlled operations
3. Precision work, to measure judgment, creative ability, etc.
4. Operations affected by an uncontrollable variable
5. Long and complex operation cycles

Even a casual inspection of the MTM tables of application data should be sufficiently convincing as to the rather meager coverage of factors generally assumed as affecting motions, times, and rate of output. Items such as fatigue, temperature, external interference, personal problems, condition of equipment, pre-positioning of tools and materials, and numerous other conditioning factors have not been taken into account. The reason should be very clear. Measurement of the effect a single variable has upon basic elemental time is in itself a rather complex task. Injecting a second variable compounds the difficulty. As additional factors are brought into the analysis, time and costs expended mount in geometric proportions, while the tendency for validity and reliability to decline invariably manifests itself.

While the technical limitation of this technique and also of the Work-Factor System, described in the next section, are properly recognized, it is assumed that an acquaintance with the fundamental principles and the basic procedures of these techniques should be of great significance to the would-be industrial manager. In particular, these modifications of ideas and methods propounded by the pioneers of scientific management bear out the premise that industrial management continues to move forward with unabated dynamism.

TECHNIQUE 3C. The Work-Factor System

Both the Work-Factor System and methods-time measurement were introduced at about the same time. The fundamental difference between these techniques is the source of standards fundamental to the techniques. MTM standards are based on the performance of a normal, or average, worker. The Work-Factor System uses an experienced, or skilled, worker for the setting of norms. In most other respects both methods show a remarkable similarity. Although the MTM approach bases elemental times on 0.00001 hour while the Work-Factor System uses 0.0001 minute, the conversions from one norm to the other can be readily effected. Thus a TMU equals 0.0006 minute while a work-factor unit equals 0.0001 minute.

The basic elemental times expressed in this fraction of a minute are in each case then condensed into tabular form for easy reading

Exhibit 13-14. Work-Factor Motion-Time Table for Detailed Analysis

(Time in Work-Factor* units)

Distance moved, inches	Basic	Work-Factors 1	2	3	4
(A) Arm, measured at knuckles					
1	18	26	34	40	46
2	20	29	37	44	50
3	22	32	41	50	57
4	26	38	48	58	66
5	29	43	55	65	75
6	32	47	60	72	83
7	35	51	65	78	90
8	38	54	70	84	96
9	40	58	74	89	102
10	42	61	78	93	107
11	44	63	81	98	112
12	46	65	85	102	117
13	47	67	88	105	121
14	49	69	90	109	125
15	51	71	92	113	129
16	52	73	94	115	133
17	54	75	96	118	137
18	55	76	98	120	140
19	56	78	100	122	142
20	58	80	102	124	144
22	61	83	106	128	148
24	63	86	109	131	152
26	66	90	113	135	156
28	68	93	116	139	159
30	70	96	119	142	163
35	76	103	128	151	171
40	81	109	135	159	179
Weight, pounds:					
Male	2	7	13	20	Up
Female	1	3½	6½	10	Up
(T) Trunk, measured at shoulder					
1	26	38	49	58	67
2	29	42	53	64	73
3	32	47	60	72	82
4	38	55	70	84	96
5	43	62	79	95	109
6	47	68	87	105	120
7	51	74	95	114	130
8	54	79	101	121	139
9	58	84	107	128	147
10	61	88	113	135	155
11	63	91	118	141	162
12	66	94	123	147	169
13	68	97	127	153	175
14	71	100	130	158	182
15	73	103	133	163	188
16	75	105	136	167	193
17	78	108	139	170	199
18	80	111	142	173	203
19	82	113	145	176	206
20	84	116	148	179	209
Weight, pounds:					
Male	11	58	Up		
Female	5½	29	Up		

Distance moved, inches	Basic	Work-Factors 1	2	3	4
(L) Leg, measured at ankle					
1	21	30	39	46	53
2	23	33	42	51	58
3	26	37	48	57	65
4	30	43	55	66	76
5	34	49	63	75	86
6	37	54	69	83	95
7	40	59	75	90	103
8	43	63	80	96	110
9	46	66	85	102	117
10	48	70	89	107	123
11	50	72	94	112	129
12	52	75	97	117	134
13	54	77	101	121	139
14	56	80	103	125	144
15	58	82	106	130	149
16	60	84	108	133	153
17	62	86	111	135	158
18	63	88	113	137	161
19	65	90	115	140	164
20	67	92	117	142	166
22	70	96	121	147	171
24	73	99	126	151	175
26	75	103	130	155	179
28	78	107	134	159	183
30	81	110	137	163	187
35	87	118	147	173	197
40	93	126	155	182	206
Weight, pounds:					
Male	8	42	Up		
Female	4	21	Up		
(F, H) Finger-hand, measured at fingertip					
1	16	23	29	35	40
2	17	25	32	38	44
3	19	28	36	43	49
4	23	33	42	50	58
Weight, pounds.					
Male	⅔	2½	4	Up	
Female	⅓	1¼	2	Up	
(FT) Foot, measured at toe					
1	20	29	37	44	51
2	22	32	40	48	55
3	24	35	45	55	63
4	29	41	53	64	73
Weight, pounds:					
Male	5	22	Up		
Female	2½	11	Up		
(FS) Forearm swivel, measured at knuckles					
45 degrees	17	22	28	32	37
90 degrees	23	30	37	43	49
135 degrees	28	36	44	52	58
180 degrees	31	40	49	57	65
Torque, pound-inches:					
Male	3	13	Up		
Female	1½	6½	Up		

Work-Factor* symbols:
- W = weight or resistance
- S = directional control (steer)
- P = care (precaution)
- U = change direction
- D = definite stop

Walking time			
Type	30-inch paces		
	1	2	Over 2
General	As single steps	260	120 + 80 per pace
Restricted		300	120 + 100 per pace
Add 100 for 120- to 180-degree turn at start			
Up steps (8 inches rise, 10 inches flat)			126
Down steps			100

Visual inspection		
Focus	20	
Inspect	30 per point	
React	20	
Head turn:		
45 degrees		40
90 degrees		60

1 time unit = 0.006 second
= 0.0001 minute
= 0.00000167 hour

* Trade-mark.

SOURCE: J. H. Quick, J. H. Duncan, and J. A. Malcolm, Jr., "The Work-Factor System," sec. 4, chap. 3, in H. B. Maynard (ed.), *Industrial Engineering Handbook*, McGraw-Hill Book Company, Inc., New York, 1956, p. 4-51.

and application. In both the MTM and the Work-Factor tables the effect of the most significant variables upon the basic elements is carefully weighted. Both techniques follow most of Gilbreth's precepts in reducing operations to basic components, finding the optimum combination, and then standardizing this sequence as the "one best way." A significant improvement over earlier motion- and time-analysis systems is the empiric foundation upon which the setting of all predetermined elemental times rests.

The Work-Factor technique was initiated by Joseph H. Quick and William J. Shea. Their initial venture in this area was made in 1934. However, the system was not widely known until 1945 when *Factory Management and Maintenance* published an account of the technique written by its developers.

As the authors of the system have defined it, a "Work-Factor is a unit used as the index of additional time required over and above the basic time when motions are performed involving the following variables: (1) manual control, (2) weight and resistance." [6] In effect, these two variables condition all the computations as presented in the Work-Factor tables. As noted in Exhibit 13-14, there are actually five classes, or degrees, of difficulty, labeled basic, one, two, three, and four work-factors. The difference between each of these classifications is established only after a careful analysis of the degree of manual control and the effect of weight and resistance upon the operation. The Work-Factor manual describes in detail the characteristics of each work-factor classification. As illustrative of this type of careful subdivision and rigid definition, manual control can be

[6] J. H. Quick, J. H. Duncan, and J. A. Malcolm, Jr., "The Work-Factor System," sec. 4, chap. 3, in H. B. Maynard (ed.), *Industrial Engineering Handbook*, McGraw-Hill Book Company, Inc., New York, 1956, p. 4-47.

viewed as (1) definite stop, (2) directional control, (3) precautionary act, and (4) change of direction.

In addition to the two variables, manual control and weight, or resistance, which directly affect the selection of the specific work-factor category, two other variables must be considered. These are (1) the body member involved and (2) the distance moved (in inches). The body members for which specific time values have been computed are finger, arm, forearm swivel, trunk, foot, and leg.

The Work-Factor System further stresses detailed analysis by reducing the operations to eight standard elements of work: transport, grasp, pre-position, assemble, use, disassemble, mental process, and release. In turn, these standard elements of work are, where possible, even further differentiated. Thus a "transport" can be considered as (1) a tossing motion, (2) a motion stopped by a rigid object or requiring no control by worker, (3) a motion made to an indefinite location, (4) a motion to return a body member to a normal relaxed position. A "grasp" can be (1) simple (pinch, contact, or wrap around), (2) manipulative, (3) complex, or (4) special (transfer, exact quantity, group, etc.).

To facilitate analysis, the system makes considerable use of mnemonic abbreviations. In all there are more than 56 such abbreviations, including 8 for body members, 5 for the work-factor-conditioning aspects, and 8 for the standard elements of work. These abbreviations are very useful in reducing motion descriptions into coded form. For example, moving a textbook a distance of 2 feet from one place on a desk to another spot might be expressed as A24. This would be interpreted as an arm movement over a distance of 24 inches and involving the basic work factor. If this same action pertained to a 10-pound object and necessitated a definite stop motion, the code would read A24WD. The calculation of time allowed would simply require referring to the "arm" table, reading down the "distance" column to "24" and then across. It will be noted that the figure 63 under the "basic" work-factor column differs significantly from the figure 109 under the "2 Work-Factors" column. These figures, incidentally, refer to units of 0.0001 minute; the first would mean that 0.0063 minute comprised the allotted time for the A24 action while the A24WD element was assigned 0.0109 minute. The difference is accounted for by variations in degree of difficulty between A24 and A24WD.

This condensation of pertinent information greatly facilitates analysis and presentation of results. Similarly, every elemental motion would be expressed in mnemonic form. The analyst would then con-

vert each of the coded motions into standard allowed times by referring to the tables of predetermined elemental times.

As in all work-measurement studies, this type of data is usable in the more complex analyses involving work done by two or more body members simultaneously and independently performing manual operations. In such cases, a special simo allowance is injected to adjust for this modification. Where the analysis pertains to work done by use of both hands, the typical right- and left-hand forms are applicable.

Both the MTM and Work-Factor techniques make provision for less than detailed analysis. MTM provides a simplified data modification which has already been briefly described. The Work-Factor System has similar tables for simplified analysis and an even more compact version termed the abbreviated Work-Factor System. The distinction among these variations is basically in complexity, cost, and precision. With work of a highly repetitive nature, and particularly when the work cycles are very short, detailed work-factor study might be preferable. When the operations are less repetitive and the work cycles somewhat longer and where the output is measured in smaller quantities, the simplified work-factor alternative should be recommended. Finally, if the work is of the odd-lot, job-shop, or single-order type, the abbreviated work-factor modification should be applicable.

Exhibit 13-14 is a summary of work-factor motion times for detailed analysis. Comparable tables are available for the two alternative versions. Although these tables present the data in a very concise and comprehensible form, it should be remembered that many additional tables are needed for accurate analysis. This secondary information concerns the eight standard elements of work upon which this system is actually built. Special tables, such as a Work Factor Complex Grasp Table for Cylindrical and Regular Cross-sectioned Objects Grasped from Random Piles, are also available. These special-purpose tables are very useful for fast and accurate analysis of other than conventional motions.

In addition, the category of synthetic basic-motion times is gradually being augmented by new versions. Space limitations prevent more than a casual reference to at least three other contributions to this technique. A. B. Segur's motion-time analysis, developed more than thirty years ago, is very similar to the techniques already described. This device stresses that the time required to perform basic motions tends to be constant for different individuals. Adoption of the optimum method would necessarily mean that the individuals using this method will gravitate toward the standard set by that method.

Basic-motion–time study (BMT), introduced by Ralph Presgrave and several associates, uses time units of ten-thousandths of a minute and stresses constant values for basic and standardized motions. These basic motions begin at the pause, or point of rest, just prior to the inception of the action and terminate with the parallel pause, or point of rest, which immediately follows completion of the basic motion. As in the Work-Factor and MTM systems, the basic arm, hand, finger, and body motions are identified and ascribed specific values. Variable factors, such as distance, weight, force, and precision, simultaneous arm motions, and turning actions likewise affect the calculations.

Dimensional motion times (DMT), a contribution of the General Electric Company, follows a somewhat similar pattern to that characterizing the other synthetic basic-motion–time techniques. The "dimensional" aspect refers to the emphasis placed by this technique upon the spatial aspects as the principal criteria affecting standard times requisite to the performance of basic motions.

It should be obvious from this rather summary presentation of synthetic time-standard techniques that caution should be exercised in the plant-wide or company-wide adoption of any of these methods based on predetermined-elemental-time data. Most methods- and time-study men will agree that the basic stop-watch techniques should not be haphazardly used by the inexperienced or the improperly trained. Yet the stop-watch techniques are rather simple in application and in comprehension as compared with the predetermined-elemental-time techniques.

This description and the preceding study of MTM have been included in this chapter to acquaint the would-be industrial manager with the currently available tools by means of which better decisions can be made and more effective control can be attained. Despite their seemingly scientific character, the predetermined-elemental-time techniques are such recent innovations that even their proponents stress the need for more time and more experimentation before all the "bugs" can be eliminated.

ILLUSTRATION 1. Determination of Task Times

A time study was recently conducted in a large supermarket to determine the standard time for the order-checking operation. On five successive days the time-study men observed a different operative during an 8-hour work period. The checking operation was arbitrarily divided into six major elements. Exhibit 13-15 contains the median times for the five operatives and the six elements.

Not satisfied with the results, the manager insisted that a work sam-

Exhibit 13-15. Median Times for Five Checkers and Six Elements of an Order-checking Operation

Element	Operative				
	a	*b*	*c*	*d*	*e*
1. Greet customer	0.15	0.18	0.35	0.12	0.13
2. Operate counter conveyor	0.28	0.18	0.22	0.16	0.20
3. Check items (av. = 40 per order)	0.72	0.70	0.70	0.73	0.69
4. Receive payment	0.35	0.40	0.60	0.62	0.65
5. Pack items	0.30	0.30	0.28	0.28	0.33
6. "Thank you"	0.12	0.15	0.25	0.08	0.27

pling, or ratio-delay analysis, be made the following week. The first day's ratio occurrences, on a random-sampling basis, are listed in column *A*, Exhibit 13-16. The summary of the five-day ratio-delay study is shown in column *B*, Exhibit 13-16.

Exhibit 13-16. Ratio Occurrences in the Work-sampling Analysis

Element	*A*	*B*
1. Greet customer	6	90
2. Operate counter conveyor	22	80
3. Check items (av. = 40 per order)	56	300
4. Receive payment	80	250
5. Pack items	16	170
6. "Thank you"	20	110
Total observations	200	1,000

Confused, the store manager bought a book explaining the MTM technique. Impressed by the apparent refinement and accuracy, he decided to determine standard times for order checking from the MTM tables.

The store employs a total of 12 checkers who work an average of 48 hours per week. There is only one rate of pay, presently set at $1.60 per hour.

QUESTIONS

1. Comment on the adequacy of the time-study methods used by the store manager.
2. Support your contentions with statistics and logic.
3. Would MTM or some other predetermined elemental-time-data technique be recommended in this instance?

4. Show graphically how a process flow chart, together with a greater refinement in elements, might facilitate improvements in methods and times pertinent to this case.

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CHAPTER 14

Production Control

DEFINITION AND DESCRIPTION

In the generic sense production control pertains to practically all phases of the manufacturing sequence. Specifically, however, production control, as commonly understood in industry, is limited to the functions of scheduling, routing, dispatching, and expediting. Activities such as forecasting, production planning, and inventory control are also frequently associated with the basic activity.

By definition, control simply means a conformity of being and activity with preestablished purposeful plans. Thus control implies that the situation which exists and the actions taking place are in balance with the organization's goals and the measures decreed by the decision maker for the attainment of those goals. In turn, then, production control deals with those phases of industrial management concerned with the bringing of operational plans and implementations, both major and secondary, to fruition. In this respect production control measures performance in terms of the planned norms. Where deviation of performance from plans is observed, corrective measures must be initiated.

Logically, production forecasting must precede all production planning and operational control. While considerable strides have been taken in the direction of getting better estimates of cause-effect relationships, the element of chance continues to plague production planners. There are relatively few industrial activity patterns which are

so immutable that they are impervious to the pulls and pressures of conditioning forces. Even in the very initiating phase the incidence of consumer wants or demands is mercurial in character. Frequently flights of fancy have more effect upon current demand patterns than does sound logic. Thus the production planner must contend with unpredictable forces which tend to turn attempts at scientific estimating into guesswork. Emphasis on realistic appraisal and recognition of the limitations of effective estimating should not be construed as a rationalization justifying rule-of-thumb methods. Despite the imperfections in current management methodology, empiric techniques, such as the application of probability analysis, do help raise the level of certainty in planning and controlling performance.

Production Control Functions. Until some logical estimate of future needs is determined, it is not feasible to proceed into the production-planning phase. This activity always assumes that the basic long-range plans and all the immediate objectives have been set by top-level administrators. Production planning then converts these assumptions into manufacturing terms and goals. Items such as the economic lot size, the balance of operations and productive capacity, the specific operational sequence, the time factor, the availability of materials and tools, the effective utilization of manpower, and similar topics, constitute the functions of production control.

It seems reasonable to assume that scheduling should be one of the first steps in production control. The allocation of specific times, equipment, and manpower to given jobs in a sense creates order in the production process. Responsibility is pinpointed. Each component's contribution is viewed as a fragment of the over-all task.

In most texts dealing with this subject, in addition to scheduling, the basic function of production control is assumed to include the activities of routing, dispatching, and expediting. While this subdivision has some merit, it seems somewhat superfluous. Routing considers the "where" aspects as distinguished from the scheduling "when." Dispatching is the activating phase of production control consisting in the issuance of specific orders and instructions for certain activities to follow prescribed courses as planned. Expediting is simply the giving of individual attention to a work order, facilitating its movement through the prescribed sequences. Scheduling, routing, dispatching, and expediting are actually different aspects of the basic production-control function of putting manufacturing plans into action.

Scheduling, since it pertains to the relative times allocated to specific operations in the manufacturing sequence, is affected by (1) the quantity of the product to be made, (2) the pertinent manufacturing proc-

ess (intermittent or continuous), (3) the policy of producing to order or for stock, (4) the procurement cycle, (5) the extent of delays necessitated by handling and transport, (6) the availability of equipment and manpower, (7) the adjustments due to setup and maintenance, and (8) the customary work habits, procedures, or practices.

Master schedules, frequently set up in Gantt-chart form, are extremely useful for clear and concise representation of over-all timing. Portions of the master schedule can then be expanded into more detailed schedules related to specific operations and rigidly designated times. In other words, the master schedule is equivalent to a summary of the manufacturing objectives for a designated period. This type of schedule is particularly useful for long-term planning.

While on the subject of master schedules, emphasis should be given to the most obvious limitation of a master schedule which is not properly translated into more detailed schedules. In such a case there is an increased probability that over-all objectives accepted in principle will fail to materialize in actual practice. This, by analogy, is the prime weakness of all utopian plans and aspirations. Utopian distant dreams represent laudable objectives only if steps are taken to convert the ideal into tangible terms. Generally, however, this type of planning fails because it does not translate the ideal into the attainable. The multitude of variables so vital to accomplishment tend to be completely overlooked in the visionary approach. This digression into the limitations of utopian planning has considerable bearing not only upon the sociopolitical aspects of planning but even more particularly upon the economic aspects. The utopian label can most certainly be applied to any businessman who sets up broad long-range objectives and then fails to translate these objectives into more immediate and more detailed plans.

The determination of a workable production schedule is intimately concerned with the eight items already mentioned. In turn, these topics relate to functional areas so important that individual chapters have been devoted to them in this text. For example, a comprehension of machine capacity is paramount in effective scheduling. Consequently, the production planner must be acquainted with at least the principles and basic techniques pertinent to equipment utilization as set forth in Chapter 11. He must, likewise, understand the principles and practices applicable to manpower allocation. A specific job can be properly accomplished only when a specific man is assigned to that task. Thus the production planner must have a working knowledge of job descriptions and requirements. It is to his interest to comprehend the fundamental features of job evaluation as explained in Chapter 17.

Similarly, the production planner must have an adequate acquaintance with each of the several functional components of the manufacturing cycle.

The Manufacturing Order. Although there are a great many types of production control systems, varying according to industry, production process, scale of operation, complexity of manufacturing sequence, custom, etc., in every case the actual procedure begins with a formal authorization for the operation to be performed. This order to manufacture is actually the crystallized form of production planning—the culmination of the decision-making process in a concrete decision. The manufacturing order provides necessary data such as the name or code number of the customer, a description of the item to be made, its components, materials to be used, dates for completion of components and final fabrication, specific costs, etc. Attention is called to this rigid procedure for recording data since it is this emphasis on the empiric method and classified facts which helps differentiate scientific management from rule-of-thumb production control.

Continuing this procedure of production control through written and detailed manufacturing orders, a variety of subsidiary forms are generally needed. These include the individual orders to specific departments, indicating the exact operations to be performed. It is only after this issuance of the authorization to proceed that the scheduling, routing, dispatching, and expediting operations can be activated.

The exactness as to time, place, quantity, quality, cost, sequence, order number, etc., manifest in the manufacturing order, must likewise be adhered to in the subsequent procedures. Thus, for example, in routing there must be a careful identification of the orders, parts, departments, machines, operations, quantities, etc., requisite to the particular flow or sequence of activities selected for the given manufacturing order. Once again, it is this definitive action, together with the concrete evidence in written form of the decisions made and fulfilled, which warrants the use of the term *scientific* as applied to this type of industrial management.

Production Control Mechanisms. As previously mentioned, there is considerable diversity as to types of production control systems. Probably the most meaningful differentiation can be made on the basis of relative complexity. The more complex systems are generally found where (1) there is a multitude of diverse products, (2) numerous components are to be assembled, (3) there is considerable stress on custom-making and "to-order" items. The more complex the type of manufacturing, the greater is the probability that more of the production control mechanisms will be utilized and to a greater degree. The *Produc-*

tion Handbook classifies production control mechanisms in five broad categories:[1]

1. Production control boards and mechanical systems
2. Visible index or card-record systems
3. Gantt-type charts
4. Punched-card and tabulating equipment
5. Duplicating or printing equipment

In turn, each of these broad classifications has numerous adaptations. For example, the production control boards and mechanical systems include:

1. Small three-pocket wood racks (machine loading)
2. Hook boards
3. Pocket-strip or grooved-label strip boards
4. Spring-clip panel boards
5. Tape or string boards
6. Index-visible boards
7. Racks with movable data units
8. Pictorial boards

Each of the above eight types of control boards and mechanical systems is adaptable to circumstance; hence there are many variations of all eight forms. Certain of the techniques have had rather wide acceptance. For example, a movable-tape production control board with the trade name Produc-Trol is adaptable to practically any type of industrial control. In this system, record cards are inserted in specially designed pocket panels on the left-hand side of the board. This permits easy identification of the item being "controlled," since only the pertinent information shows through the panel. To the right of the record card is a series of peg holes identified by pertinent labels at the top of the pegboard. These labels can designate time or quantity. In the Produc-Trol each card, as shown in its panel, has two lines of peg holes. The upper line is used for planning purposes while the bottom indicates actual progress. Specially designed signal pegs, in twelve contrasting colors and four different shapes, can be used with this board. The tape peg is, just as the term indicates, a peg with a tape attached. A simple mechanical device provides a tension on the tape so that it is kept firmly in place regardless of the peg hole being used. Thus a very concise graphic presentation is available for comparing scheduled work with actual production.

Each of the five broad categories of production control mechanisms has numerous modifications tailored to meet special production con-

[1] L. P. Alford and J. R. Bangs (eds.), *Production Handbook,* The Ronald Press Company, New York, 1955, p. 191.

trol aspects or to adapt the technique to individual-industry characteristics. A better comprehension of these many variations can be obtained only by reference to a special-purpose text or an industrial management handbook. Space limitations permit a more detailed analysis of only one of these techniques—the Gantt chart, which is discussed as technique 4 of this chapter.

The very magnitude of the production control function and the tremendous variety of circumstances under which it operates make generalization as to specific techniques, immediate objectives, and basic principles rather hazardous. One of the best summaries of these aspects of production control is presented in the *Industrial Engineering Handbook*.[2]

1. The type of manufacturing, not the kind of product, determines the kind of system required. . . .

2. The single, basic governing feature is the number of parts involved. . . .

3. The complexity of control will vary directly with the number of assemblies involved.

4. Time is the common denominator of all scheduling.

5. The size of the plant or division has relatively little, if anything, to do with how involved a production-control system need be. . . .

6. In the preparation of basic data or documents, the constant information should be separated from the variable. . . .

7. The exception principle should be followed wherever possible in reporting progress in all phases of production control in preference to the positive, or 100 per cent, method. . . .

8. Real production control is a before-the-fact control, while recording or scorekeeping is only an after-the-fact by-product. . . .

9. Cost control should be a by-product of planning and dispatching.

10. Original writings should be held to a minimum; they are expensive and generate errors. . . .

11. The number of units in process (actually being worked upon) will usually be equal to the product of the number of periods (months, weeks, days) in the manufacturing cycle and the number of units to be completed during each of those periods.

12. A frozen or firm shipping schedule should always be equal to or greater than the manufacturing cycle of the end product being scheduled. . . .

13. All papers, prints, materials lists, job cards, cost records, and the like should be copies of one or more of the following four basic documents:

a. Schedule—the written authorization to produce a certain quantity of product by a certain date

[2] Thomas M. Landy, "Production Planning and Control," sec. 6, chap. 1, in H. B. Maynard (ed.), *Industrial Engineering Handbook,* McGraw-Hill Book Company, Inc., New York, 1956, pp. 6-7 to 6-8.

b. Drawing—the design engineering instructions for producing a product

c. Material list—a listing of all raw materials and components comprising a product

d. Planning record—the information on lead times, delivery dates, and the like needed for planning production

Principle of Simulation. It is generally assumed that time and costs are saved when two or more operations can be performed at the same time by one operative or by one machine. Obviously, there are considerable planning, analysis, standardizing, measuring of capacity, balancing of cycles, and comparison of cost and effectiveness of various man-machine combinations requisite to the proper application of this principle. While simulation does not necessarily involve any specific formulas for achieving the optimum combinations, it does, nevertheless, necessitate improvements in the usual form of production control. By definition simulation results from either (1) the performance of multiple activities at the same time by the same operative or mechanism, generally on the same work-in-process, or (2) the performance of two or more different phases of an activity cycle upon two or more pieces simultaneously.

Considerable planning and control are necessary if simultation is to be applied effectively. This is particularly true since the minimum over-all production time for the operations performed simultaneously tends to approximate the length of the longest work cycle involved. This is particularly evident from observing the data on most right-hand–left-hand charts. In practically every instance where both hands begin operations simultaneously and where, theoretically, both hands should end their cycles at the same time, the character of the work makes it impossible to have two cycles of precisely the same length. Consequently, the shorter-cycled operation can either be terminated sooner or be dragged out to approximate the longer cycle. This same phenomenon applies to the balancing of machines, men, or men and machines.

This aspect of production control is very intimately related to several other production techniques. The individual vested with the production control responsibility must be familiar with methods analysis, time study, capacity measurement, and even with job descriptions. He must be acquainted with control boards, Gantt charts, and other scheduling and routing devices. Knowledge and proper application of these tools can shorten considerably the time necessary to complete a given job. The impact of the principle of simultation is particularly evident in the assembly-type industries, and especially in mass production. More recently, the limelighting of automation has brought into

better focus the economy of simultaneous performance of several activity cycles upon a piece of work. Actually, the principle of simultaneity, together with feedback control and serialized synchronization, serves to differentiate automation from other forms of mechanization.

TECHNIQUE 1. Organization of Productive Capacity

A brief reference was made in the beginning of Chapter 3 to the several classifications of production methods. The functional division was assumed to include the analytical, synthetic, conditioning, and extractive processes. The classification of production, according to sequence, was divided into continuous, repetitive, and intermittent production. Each of these production methods has individual characteristics which necessitate modifications in the generic production control techniques.

Even more important is the manner in which the production facilities are organized on a departmental basis. The departmentalization principle stresses that all the production facilities should be so arranged that materials movement will be kept to a minimum consistent with the most effective processing of that material. Fundamentally there are three universally recognized methods of departmentalization: (1) product layout, (2) process layout, or (3) a combination of these two. Obviously, in some instances, the production method, on either the functional or sequential basis, is, in a sense, predetermined by an industry's prevailing technological characteristics. In turn, the functional and sequential production methods considered technologically preferable in a given plant determine the type of departmental layout to be used. Despite this nexus, there is, however, a rather broad area of indifference where compromise and substitution are feasible.

Product layout, sometimes referred to as line layout, stresses the logical arrangement of all equipment and work stations in the order determined by the operational sequence. The product movement from a prior operation to a subsequent phase should be in as straight a line as possible and should cover a minimum distance. This characteristic gives the designation of "line" to the layout method. The term *product layout* obviously applies to the paramount stress given to the logical and sequential pattern in the arrangement of facilities according to the steps necessary to process a given product.

Among some of the outstanding features of product, or line, layout is this stress on logical organization of all productive facilities on a time-use basis. Not only does this serve to simplify the planning and control functions but it also tends to build a balance into the arrangement of productive capacity. While this type of equipment and work-

station layout tends to facilitate fulfillment of the production control functions, such balance of capacity evidently can be achieved only through intense preplanning and proper control of a multitude of variables, particularly those associated with technological factors. The tremendous diversity in productive equipment capacity, make, and function, the great variety in possible combinations of equipment, space limitations in placement of equipment, need for flexibility as to products manufactured, degree of mechanization or automation, and similar factors affect the installation and use of the line, or product, layout.

Generally only one product or a group of very closely related products will be processed on the product, or line, layout. This rigidity limits the use of this method to quantity production of a relatively standardized item. In this respect the technique possesses all the generally known advantages and limitations of mass production. These characteristics are adequately summarized in Exhibit 14-1. In particular, it should be stressed that for optimum production control proper attention must be given to the balancing of capacities and the minimizing of interruptions to any component of the operational sequence.

Exhibit 14-1. Twelve Fundamental Characteristics Differentiating Product and Process Layout

Product layout	Characteristic	Process layout
Much	Danger of bottlenecks	Little
Few	Written instructions	Many
No	Detailed scheduling	Much
Large, constant	Volume output	Small, variable
Very little	Product diversity	Considerable
Relatively short	Production cycle	Much longer
Only incidental	Supervision	Specialized, much
Special-purpose	Equipment	General-purpose
Relatively high	Investment	Moderate
Machine	Paced	Man
Little, in-process	Inventory	Considerable
Semi- or unskilled	Labor	Skilled

Process, or functional, layout stresses the grouping of similar or very closely related equipment in separate departments. This arrangement of facilities means that all functional operations of one type must be routed to these individual departments. As the manufacturing cycle becomes more complex and as the number of products and components increases, functional layout, obviously, tends to present more problems to the production planning and control department. Whereas

line layout can figuratively be said to have a built-in production control system, modifiable only by comparable changes in equipment layout or in production practices, process layout can be viewed as being relatively flexible for production control purposes. This flexibility need not, however, necessarily be viewed as an advantage. Line layout has already been postulated as being optimized in terms of the available productive capacities. Functional layout has no such premise. The nature of orders to be processed will determine in large measure the manner in which each department, each work station, and each piece of equipment will be scheduled for participation in the production sequence.

The basic characteristics of process, or functional, layout, as summarized in Exhibit 14-1, have some very important ramifications. These are fittingly expressed by Ireson as follows:[3]

> The functional layout is characterized by such conditions as:
>
> 1. The presence of a skilled labor force, capable of setting up the machine, reading blueprints, and determining the proper sequence, feeds, and speeds for efficient operation.
> 2. Highly specialized supervision in each department.
> 3. Many different production orders in process at the same time, resulting in a need for careful control and direction.
> 4. Large storage space in each department for work-in-process and large in-process inventories.
> 5. Extensive materials-handling operations; frequent movement of small quantities over medium and long distances.
> 6. Generalized materials-handling equipment, requiring a large amount of labor and supervision.
> 7. The need for large volumes of instructions, written and oral, to effect desired movements and operations at desired times.
> 8. Frequent changes in workers' jobs and frequent instruction.
> 9. No mechanical pacing of the work.
> 10. A possibility of making greater use of machines and requiring less capital investment.

Common sense should indicate that no one enterprise nor even a single moderately sized plant will be restricted solely to either product or process layout. Both can be used even in the same plant and on the same floor if deemed expedient and efficient. Moreover, with the rather rapid strides made recently in technological improvements and with the tendency toward diversification in output, it is highly unlikely that any large-scale enterprise can limit operations to a single, un-

[3] W. G. Ireson, sec. 8, in W. G. Ireson and E. L. Grant (eds.), *Handbook of Industrial Engineering and Management,* Prentice-Hall, Inc., Englewood Cliffs, N.J., 1955, p. 575.

changeable form of layout. As a consequence, the combination layout, a hybrid version, can be used effectively in many situations. This method is particularly adaptable where a number of products have kindred sequences in processing requiring relatively the same functional operations. However, if the volume for these products is not sufficiently high, product layout cannot be justified. Hence the compromise. In this case the functional departments are so arranged that the multiproducts can move in process in relatively direct routes with a minimum diversion into special processing areas. Thus many of the benefits of both product and process layout are incorporated in this compromise method.

From this brief description of productive-capacity arrangement it should be evident that the production planning and control functions and techniques are in large measure dictated by technological considerations. Despite this limitation, however, there is a relatively wide latitude in the kind of technique to be used, its interrelationship with other management functions, and the measures employed to attain maximum effectiveness of that technique.

TECHNIQUE 2. Forecasting

Accurate production planning and control is not feasible without a sound estimate as to future demands for the goods and services in question. Yet shifts in consumer preference, both as to intensity and direction, are extremely difficult to predict. While considerable strides have been made in substituting the empiric for the intuitive in estimating future consumer demands, so many variables are involved that there are virtually no cases in the industrial field where correlation of expected consumer reaction and actual consumer behavior can always be measured with scientific precision. This is even true where demand is relatively inelastic. Elasticity, in this instance, refers to the effect that changes in price have upon demand for the product. Absolute inelasticity exists when price changes have no effect upon the total effective demand. The relatively more inelastic is a particular demand pattern the easier is it to predict future needs. Forecasting is also facilitated when the correlation between price and demand invariably follows the same rigid pattern. However, even where the coefficient of elasticity has been derived from valid studies, entrepreneurial decisions made solely on this basis tend to be rather tenuous.

This stress on caution is not meant to be an indictment of forecasting techniques. Even in those instances where price-demand patterns do not have measurable relationships, or where variables are too numerous or too difficult to isolate and to measure, steps taken toward

giving forecasts a rational basis are invariably beneficial. Such forecasts have a distinct value in modern industry, but only if all conditioning factors are properly recognized and weighted.

Techniques of sales forecasting are categorized as:

1. Opinions, either Individual or Collective. The effectiveness of forecasts of this type depends intimately upon the technical competency, the analytical ability, and the sound judgment possessed by those making decisions on the basis of these opinions. As was stressed in the section describing high-speed computers, the human mind is still superior to the most complex high-speed computer in sifting certain types of information. Then too, mechanical gadgets are completely impotent in rendering judgments. Thus an opinion ventured by a properly qualified individual should not be treated lightly. However, internal and external conditioning factors and even the force of circumstance must never be overlooked.

2. Historical Background. One of the simplest devices in forecasting is to assume that comparable results will be had from similar sets of circumstances. Analyzing past records can then yield useful information as to the circumstances which prevailed at a given time and the performance flowing from that specific situation. While this reliance upon historical records can be very helpful for short-run analysis, and particularly for relatively static and inelastic situations, such estimates tend to lose their value in a dynamic society.

3. Sampling Techniques. As explained in other chapters, sampling techniques are concerned with the drawing of inferences relative to a statistical universe on the basis of characteristics observed in samples taken from that universe. If this technique is to be used properly, it is obvious that the sample or samples analyzed must be truly representative. Too frequently amateur ventures at inference making on the basis of nonrepresentative samples yield improper estimates, which lead to poor decisions, ineffective control, and retrogression in competitive position. A fairly representative sample, on the other hand, whether random or stratified, can be useful for at least rudimentary estimating purposes.

4. Statistical Analysis. This technique is a significant improvement over the three other methods. Its reliance upon facts gives it an objective base. Use of probability theory tends to minimize guesswork and risk. Translation into standardized terminology, charts, equations, tables, symbols, etc., permits more meaningful comparison and more valid analysis. The technical competency requisite to proper application of this technique necessitates considerable training in statistical

methodology. Another limitation can follow from overemphasis on minutiae, which can lead to excessive expense. Finally, as shown in illustration 2, Chapter 7, even the predictions of experts frequently turn out, in the light of subsequent experience, to be completely unreliable.

Some of the factors responsible for the variance between prediction and performance in the sphere of industrial management have been discussed in previous chapters. For example, the influence of time as a conditioning variable in decision making has been stressed in corollary 2, Chapter 7. Then too, it has been pointed out that in many instances it is impossible to segregate all pertinent variables. In many cases, even where conditioning forces are identifiable, it is not feasible to attach numerical values to these terms. Of even greater significance is the difficulty inherent in the control of many important variables.

Despite these limitations some strides have been made in the better comprehension and wider application of regression-and-correlation analysis. Indexes are commonly used in this connection. Before venturing into this field of scientific forecasting, the judicious decision maker must, obviously, attain a high degree of certainty as to the adequacy of his basic information and the inferences drawn therefrom.

While forecasting is frequently associated with the subjects of sales and inventory procurement, it should be clear that forecasting is integral to every area requiring decision making. The formulation and implementation of every policy, plan, procedure, and practice requires knowledge as to future needs and future occurrences. Yet prediction in the industrial sphere can scarcely approximate prophecy. Uncertainty inevitably injects the element of risk. In the effort to control or to minimize these risk-producing factors, scientific management constantly strives to develop techniques for isolating the elements which cause uncertainty. Once located, they must be measured or weighed, at least approximately. Then, neutralizing or countervailing forces must be released to nullify the effects of the undesirable variables. Exhibit 14-2 shows in straight-line fashion five fundamental phases in the forecasting sequence. This analysis is by no means complete and is intended merely to highlight the importance of past performance, conditioning factors, range-type forecasts, the availability of adequate resources, and the final application of criteria of success in prediction. In actual practice this sequence is simply part of an endless cycle. Invariably a new sequence is engendered upon the completion or even before the completion of an in-process forecasting cycle. Better acquaintance with forecasting techniques invariably facilitates the work

Exhibit 14-2. Basic Components and Sequence in Forecasting

Analysis of past performance →	Isolation of factors conditioning performance →	Setting of forecasts →	Providing facilities and finance →	Measuring fulfillment or failure
1. In absolute terms	1. Intracompany	1. Long-run a. High b. Low	1. Available capacity	1. Extent to which forecasts have materialized
2. Relative to market	2. Intercompany		2. Capacity and load factors	
3. Relative to major competitors	3. Total economy	2. Immediate a. High b. Low	3. Need for new facilities	
4. Relative to realizable potential	4. Noneconomic		4. Adequacy of financing	
			5. Sources of additional funds	

of the production planner. In fact, production planning and control is so intimately associated with the process of prediction that it would be virtually impossible to separate these activities.

TECHNIQUE 3. Economic Lot Sizes

The determination of economic lot sizes and economic ordering quantities is an important part of the production control function. The lot-size and the ordering-quantity aspects are very similar, although some authorities differentiate the two by assuming that the first applies to the manufacturing phase proper while the latter is an adjunct of procurement. Such a differentiation seems to be mainly a matter of semantics. In either case it is important to have the needed materials and parts in the exact quantities and proportions at the proper work stations at the right time. Bottlenecks, imbalance, idle equipment and manpower, high costs, and confusion result from a disjointed or inadequate flow of materials, parts, and goods. Excessive costs incident to storage, product deterioration, interest charges, etc., follow from disproportionately high lot sizes and ordering quantities.

In the manufacturing phase the ideal as to economic lot sizes seems to be realized in the serialized and synchronized type of manufacturing where all materials parts and goods move in such a precise se-

quence that waiting time is reduced to an absolute minimum. This hypothetically perfect balance is, however, seldom attained in the sphere of manufacturing. Circumstances such as (1) changes in demand patterns due to shifts in consumer tastes, (2) qualitative imperfections, (3) nonavailability of productive factors, (4) equipment breakdowns, (5) inadequate transport and distribution facilities, etc., tend to impede attainment of the ideal. Consequently, it becomes necessary to assume that practically all materials, parts, goods in process, and finished products will spend some time in storage prior to, between, or after manufacturing cycles.

Waiting time can be expensive, particularly when a sizable portion of the enterprise's working capital is tied up in slow-moving materials and products. In the manufacturing phase the economic lot size can be visualized as the point of equilibrium between the pull of two opposing forces, namely, preparation costs and waiting costs. The preparation-cost category includes costs associated with the initiating of manufacturing orders, process setup charges (including unusual expenditures for special jigs, fixtures, dies, etc.), specific scheduling, routing, dispatching, and follow-up costs, pertinent bookkeeping expenses, and special executive and supervisory costs incurred in planning and processing the lot in question. It should be noted that this entire category of costs can be viewed as "fixed" relative to a single preparation or order. However, it must not be assumed that this fixity is an immutable characteristic. Actually, increased supervision, more careful setup and breakdown of facilities, and a similar greater stress on all the preparatory and special-attention phases can increase costs per preparation considerably. However, since there is generally no measurable increase in preparation costs attributable to fluctuations in the lot sizes being manufactured or being ordered, these preparatory costs are characterized by a fixity in respect to a given lot. Assuming that costs per preparation remain constant, it should be obvious, then, that as the lot size, designated as N, increases, the preparatory costs, labeled P, decrease proportionately per unit. This should be clear from the simple expression

$$\frac{P}{N} = \text{unit costs incurred in preparing a given lot for processing}$$

If the sum of all costs in the P category is \$500 and the lot size is 10,000 units, the average unit charge incurred in preparing this lot for processing is \$500/10,000 = \$0.05. This characteristic of fixity in preparation costs places a premium upon manufacturing and ordering the largest possible size lots. The logic for this tendency should be

obvious. Since P remains constant, any increase in units comprising N means a proportionate decrease in the charge attributable to each unit of product. Conversely, processing smaller lots results in each unit comprising the lot being ascribed a bigger share of the preparation costs.

Inventory carrying charges have somewhat different characteristics. They are basically a function of value and of time. Whereas preparation costs tend to remain constant per order but vary per unit according to the size of N, inventory carrying costs usually remain constant per unit and thus yield a variable total sum, determined by the size of the lot, average unit value, the carrying-charge rate, and the time factor. For example, assuming a 10 per cent levy for interest and closely related charges, an item priced at $10 and kept in storage or in process for an entire year would incur an expense of $1 for that period. Proportionate charges must be levied for all goods in process or in storage for periods of less than or more than the calendar or fiscal accounting period.

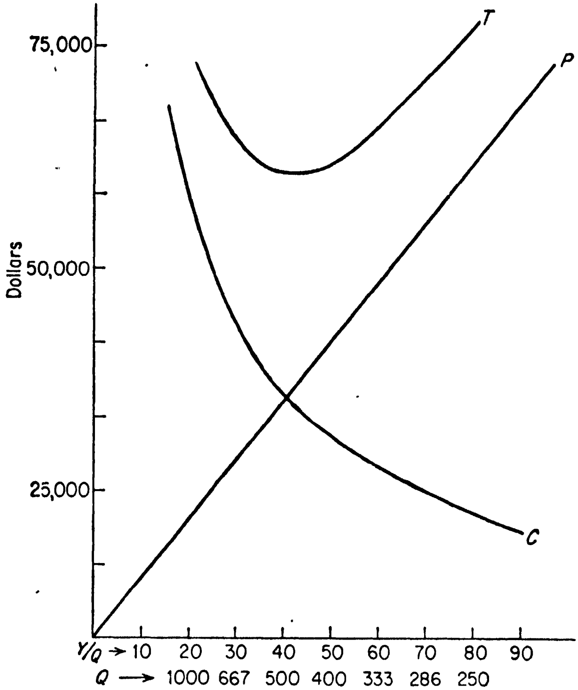
Since variable and fixed costs are discussed in greater detail in the cost control chapter, it would be superfluous to elaborate upon this topic at this point. It should be clear, however, that there is an inverse relationship, for purposes of determining economic lot sizes and ordering quantities, between the fixed preparatory costs and the variable inventory carrying charges. It is imperative for control purposes to find the point of equilibrium between these two sets of costs, each pulling in the opposite direction.

The basic characteristics of these two categories of cost are evident in Exhibit 14-3. This graphic presentation shows the interrelationship of total preparation costs and total inventory carrying charges as variations are made in the number of lots ordered or processed. The first designation, Y/Q, on the base line refers to the number of lots to be ordered in the course of a year if the optimum cost combination is to be attained. The second designation, Q, indicates the economic lot size.

Inventory carrying charges are shown as a curved line C. Presumably, as the number of orders per year increases, average inventory decreases with subsequent diminishing of total inventory carrying costs. Preparation costs are depicted by the straight line P, on the assumption that each additional preparation adds a constant sum to total preparation costs.

The logical solution, considering the diverse patterns of lines P and C, is to find the point at which $P + C$ equals a minimum. A simple graphic presentation of the various possible combinations of $P + C$ is

Exhibit 14-3. Economic-lot-size Graph



shown in the curve T. It is obvious from an inspection of line T that the optimum combination is somewhere between 35 and 45 lots, ranging from about 600 to 350 units each.

In order to use the graphic technique meaningfully and to compute the optimum lot size arithmetically, the following information is necessary:

Q = economic lot size, to be computed
Y = annual requirements
P = preparation costs
U = unit cost of the item
C = inventory carrying costs, in decimals

Postulating a situation where $Y = 20{,}000$ units, $U = \$400$, $P = \$625$, and $C = 25$ per cent, an exact reading of the chart would show that the lowest combination of $P + C$ is \$50,000, at which point $Q = 500$.

The logic underlying the graphic presentation can best be expressed through an explanation of one of the more commonly used economic-lot-size formulas, $Q = \sqrt{2YP/UC}$.

The formula is derived from the simple assumption that at the

optimum point $P = C$; that is, total annual preparation costs are equal to total annual inventory carrying costs. It follows logically that if Y equals annual requirements of the item and Q is the theoretically economic lot size, then Y/Q equals the number of times orders must be placed during that particular year. A simple multiplication of the number of lots ordered times the cost of preparing one order, that is, $(Y/Q)P$, provides a total annual charge for preparing the orders.

Similarly, if Q is the economic lot size and consumption or processing proceeds in a steady and sequential pattern, then theoretically the inventory of this item will range from Q to zero, with $Q/2$ being the average annual inventory. The quantitative aspect of average annual inventory $Q/2$ can be converted into value terms by inserting the unit cost factor. Thus $(Q/2)U$ represents the average total value of inventory in this particular case. Multiplying $(Q/2)U$ by the inventory carrying-cost rate C provides $(Q/2)UC$, which is the total annual inventory carrying charge for this item. Substituting $(Y/Q)P$ for P, and $(Q/2)UC$ for C in the equation $P = C$ provides $(Y/Q)P = (Q/2)UC$. A simplification process yields:

$$2YP = Q^2UC$$

$$Q^2 = \frac{2YP}{UC}$$

$$Q = \sqrt{\frac{2YP}{UC}}$$

In the case of the situation previously described where $Y = 20{,}000$, $U = \$400$, $P = \$625$, and $C = 25$ per cent, the economic lot size would be computed in the following manner:

$$\begin{aligned} Q &= \sqrt{\frac{2YP}{UC}} \\ &= \sqrt{\frac{2 \times 20{,}000 \times 625}{400 \times 0.25}} \\ &= \sqrt{\frac{25{,}000{,}000}{100}} \\ &= \sqrt{250{,}000} \\ &= 500 \end{aligned}$$

If the economic lot size is 500, then Y/Q, or $20{,}000/500 = 40$, the number of 500 unit lots which should be processed in that year. The total preparation costs can be computed by multiplying Y/Q, the

number of lots, times P, the cost of the order. Thus $40 \times \$625 = \$25{,}000$ total annual preparation costs. Since $(Y/Q)P$ has been shown to be equal to $(Q/2)UC$, then the combined preparation and inventory carrying costs equal \$25,000 + \$25,000, or \$50,000.

Proof that this is the minimum combination of these costs can be obtained by computing comparable figures for other size lots. Thus if the entire year's requirement of 20,000 units were purchased or produced in one lot, preparation costs would amount to only $1 \times \$625 = \$625$. Average inventory, $Q/2$, would equal 10,000 units, each with an average value of \$400. The \$4 million average inventory value at a 25 per cent carrying-charge rate would mean that these costs reach the fantastic figure of \$1 million. Preparation costs and carrying charges would total \$1,000,625.

On the other hand, if a version of the hand-to-mouth inventory policy were followed and only 20 items were ordered at a time, inventory carrying costs would dwindle to a mere \$1,000. Preparation costs, however, would be computed as 1,000 orders $\times$ \$625 = \$625,000.

In arriving at a specific economic lot size or ordering quantity, it is generally imperative that common sense temper the conclusions arrived at arithmetically. Thus, for example, if the product is customarily measured by the gross, then the economic lot size might be set at $3 \times 144 = 432$, or $4 \times 144 = 576$. This should be evident from the "trough" portion of the T curve, which indicates that the cost differential is insignificant over a range of lot sizes. It should also be noted that as Q diminishes, the curves P and T tend to become identical. This follows from the premise that ordering a minimum quantity means that the item will be put into process or into consumption almost immediately. Waiting time is thus drastically reduced. On the other hand, as Q is maximized, T and C tend to meet. Once again the logic should be obvious. A significant reduction in the number of orders means a sizable decrease in the total preparation cost while inventory carrying charges mount rapidly as the average size of inventory increases.

Finally, caution should be recommended in the use of economic-lot-size charts, tables, or equations, particularly where quantity discounts are important. The decision maker must make the requisite adjustments arising from such quantity discounts, showing the modifications in the charts, tables, or equations. Actually, the quantity discount simply injects a new unit-price schedule into the calculations. Similarly, changes in any of the pertinent variables must be handled in a comparable fashion.

By means of the economic-lot-size technique the decision maker,

vested with the production and inventory control functions, can substitute an orderly procedure for the less systematic reliance on custom or guesswork. The important concomitants of this scientific approach —the obviously more effective control of production and the lowest combination of preparation and inventory carrying costs—make this technique a valuable adjunct of scientific industrial management.

TECHNIQUE 4. Gantt Charts

One of the best-known and most widely used production control techniques is the chart developed and popularized by Henry L. Gantt, scientific-management pioneer and Frederick Taylor's colleague. Today there are a great many versions of this technique. Fundamentally, these charts can be divided into three basic categories: planning, load, and progress charts.

The planning-type charts are graphic portrayals of desired objectives in reference to periods of time. Actually, the only difference between this type and the other two categories is the degree of immediacy. For example, load charts refer to available man, machine, or work-station capacity relative to planned use of this capacity. Progress charts merely show how productive-equipment potential, planned utilization of that capacity, and actual progress are interrelated. The similarity as to objective and means employed to attain the objective in all three basic Gantt-chart categories seems evident.

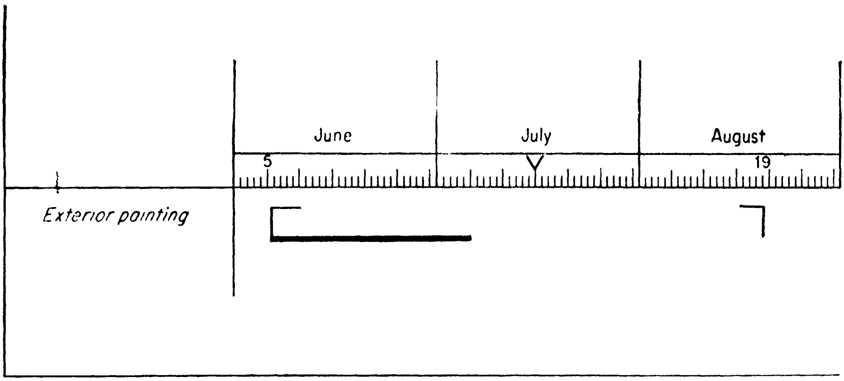
As was indicated in the description of production control boards and mechanical systems, and specifically in the explanation of the movable-tape production control board, the Produc-Trol, the purpose of these techniques is to show at a glance an index of capability as compared with accomplishment. A simple set of symbols is universally accepted to facilitate application of the charting technique. The symbol, ┌, indicates the beginning of a plan or operation. The same symbol reversed, ┐, means planned or actual completion of the project. The sign ✓,' placed at a specific point just above the time scale, indicates the exact date or hour at which a comparison is being made between the planned and the accomplished. A small figure placed in the upper-left-hand corner of a time space, for example, ┌6 ┐, can be used to indicate the quantity of work to be completed during that particular period. Comparable figures in the upper-right-hand corner of the space, ┌ 70┐, refer to the cumulative work requirements scheduled up to and including that period. In some cases individual order numbers are shown above the specific scheduled time, ┌ #6311 ┐, clearly designating that a particular activity during a specified time will be performed in connection with order no. 6311.

Exhibit 14-4 is a rather elementary illustration of how these basic principles might be applied to a very commonplace activity—the painting of a new home's exterior.

This recording tells the observer that the plan for painting the exterior of the house called for work to begin on June 5 and to be completed on August 19. A check was made on July 15 as indicated by the sign ✓, revealing that the painting was considerably behind schedule. As of July 15, work accomplished had only reached the point which was to have been attained by July 5. In this situation either an acceleration of painting pace or a revamping of the terminal date is in order.

This summary form can easily be made much more detailed and more meaningful by several modifications. The job in its entirety can

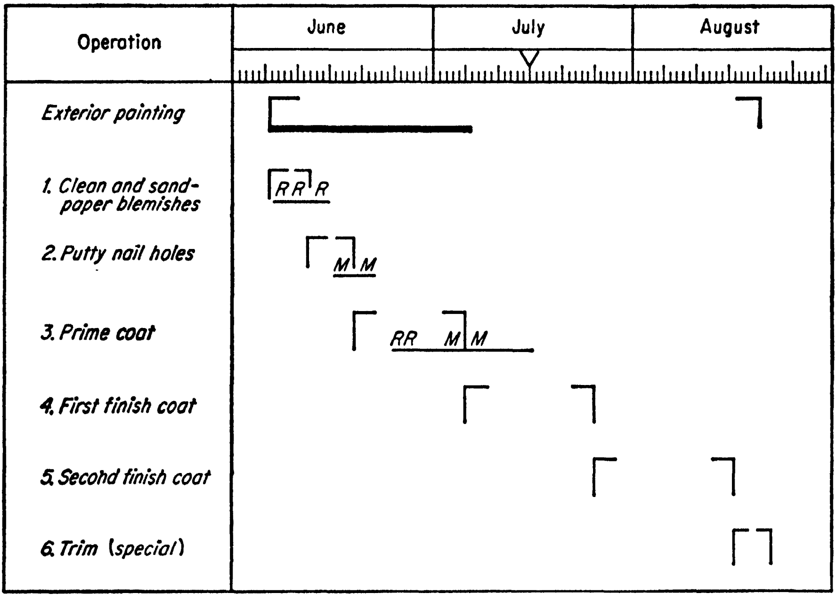
Exhibit 14-4. Summary Planning Chart



be divided into its several components. Then too, the specific interferences in fulfillment of the proposed schedule can be shown on the chart by specific symbols. Another line can also be added to show what actually took place on specific days and for each component of the basic activity. This activity line will obviously be broken at the points where interferences in the job occurred. The heavy summary line shown directly adjacent to the designation "exterior painting," in Exhibit 14-5, is actually a composite of the performance in its six subdivisions. The first of these activities, labeled "clean and sandpaper blemishes," initiated the entire process on June 5, but because of rain (*R*) on three occasions, this phase was not completed until June 13. Since completion of this portion of the work had been planned for June 10, obviously plan and performance are not in balance even at this first phase. Similarly, each of the remaining five

components of the job have specific beginning and ending times ascribed. As originally scheduled, this project should have been about halfway through the fourth phase. However, because of factors that slowed down the work, actual operations had only proceeded to the completion of phase 3—the application of the prime coat. The letters

Exhibit 14-5. Gantt Chart



R and *M*, in this instance, show that rain and lack of materials impeded effective performance. Comparable letters or symbols can be used to explain any other interference. Although many systems of mnemonics can be used to call attention to delay factors, the following seem to be generally accepted:

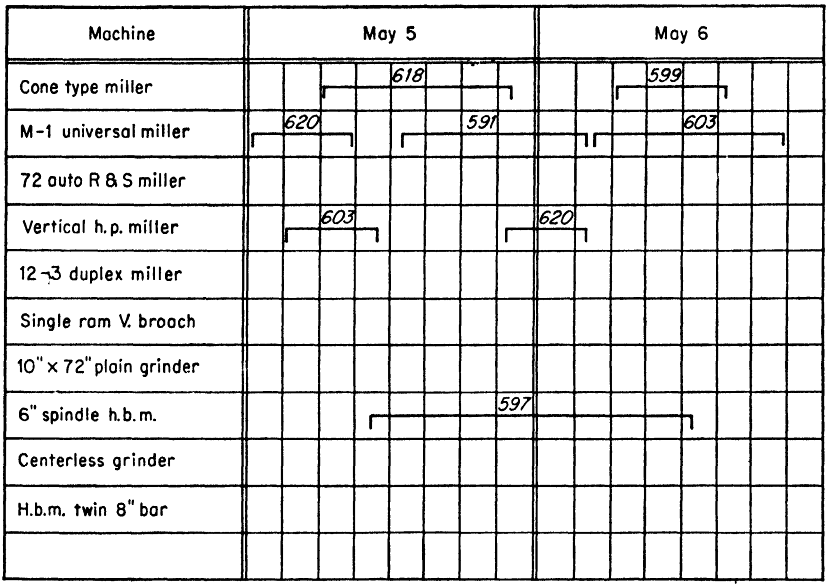
M—lack of materials	*O*—lack of orders
T—lack of tools	*R*—repairs
P—lack of power	*V*—holiday
H—lack of help	*E*—setup delay

Numerous refinements can be incorporated into the basic Gantt chart described in the two preceding figures. These refinements, while adding to the chart's complexity in construction and in interpretation, can enhance the technique's usefulness.

The commonly used Gantt machine-load chart substitutes, in the

left-hand column, the name and number of the individual machines. In the time columns, each space can indicate not only the time element but also the practical capacity of that piece of equipment relative to the time factor. Thus precise planning is facilitated through knowledge of a machine's attainable capacity. While some of the detailed procedure might vary, as, for example, the inclusion of individual lot or order numbers for both the scheduling and measuring of performance phases, the fundamental procedures tend to be identical for machine-load and all other Gantt charts. Exhibit 14-6 is an ex-

Exhibit 14-6. Gantt Chart



ample of how a series of orders might be scheduled for processing. One very obvious conclusion that could be drawn from this information is the relatively low capacity factor for this group of machines during the two-day period. If records should indicate that this is typical, the production planners should, obviously, take steps to channel more work into this department or, as an alternative, to dispose of some excess capacity.

While Gantt charts have obvious merits, it should be pointed out that this technique has considerably more utility in situations where there is great variance as to products, equipment, and manufacturing methods. Charting serialized and synchronized operation schedules is

far less complex than is the comparable translation into Gantt charts of intermittent job-lot work.

ILLUSTRATION 1. Scheduling Production of Fractional-horsepower Motors

Flexibility in production scheduling is generally determined by:

1. The extent to which equipment is already being utilized to the maximum
2. The feasibility of acquiring additional equipment
3. The economic advantages and limitations attached to working overtime or adding another shift
4. The availability of materials and components
5. Union, legal, and social regulations as to hours of work
6. Availability of additional and adequate manpower resources
7. Long-run ramifications following from expansion of the work force
8. The over-all production-cost and selling-price relationship
9. The nonmonetary considerations pertinent to prompt service and customer satisfaction

The Lamb Electric Company of Kent, Ohio, a division of American Machine and Metals, Inc., recently received an order for 2,500 S-14848 two-speed upright cleaner motors for delivery within less than a month. An immediate analysis was made to determine whether or not the item ordered deviated significantly from products presently

Exhibit 14-7. Planning for Fractional-horsepower Motor Assembly

Operation	Machine	Men	Output per day	Date	
				Begin	End
Field department					
1. Field winding	Fort Wayne Winder	1	250	4/16	4/30
2. Assemble	Bench	3	250	4/17	5/1
3. Dip and bake	Zanderol (3 hours per day)	1	250	4/18	5/5
4. Inspect		1	250	4/18	5/6
Armature department					
1. Winding	Globe Winder (two trucks)	1	500	4/16	4/22
2. Connecting	Bench (two trucks every other day)	2	50 per hour	4/17	5/1
3. Placing	Bench (5 hours every other day)	4	25 per hour	4/18	5/2
4. Dip and bake	Tank and oven (two trucks every other night)	1	500	4/18	5/2
5. Machining	Machine shop	10	250	4/21	5/5
6. Balancing		1	250	4/22	5/6
7. Inspection			150 per hour		
Motor assembly	Bench	4	250	4/23	5/7

being produced. After study of pertinent data, it was decided that the only difference, namely, in the winding in the field, was not of great consequence. The next step dealt with the identification of the limiting factor, which in this case was the winding of the fields. Careful study indicated that with current available facilities the field department could produce approximately 250 units per day. All other operations in both the field and armature departments were then arranged in balanced cycle, pegged to the field-winding limiting factor.

Exhibit 14-7 summarizes the information as to operations, their sequences, planned output, men and machines to be used, and dates for starting and completing each operation.

QUESTIONS

1. Plot the information in Gantt-chart form.
2. Is this production planning example consistent with the techniques used in determining economic lot size?
3. As a medium-sized manufacturer of fractional-horsepower motors, what forecasting methods might you use to facilitate production planning and control?
4. When, as in this case, an unexpected large order is received, what considerations should guide your decision relative to expediting that order?

ILLUSTRATION 2. Raymond's Formula for Economic Lot Quantity

The formula $Q = \sqrt{2YP/CU}$, used in this text to illustrate the logic by which economic-lot-size measures are derived and the manner in which they can be applied, is rather limited in so far as it does not account for some rather important variables. Authorities on this subject have recognized these limitations and have attempted to attain precision in measurement by devising more accurate, but at the same time considerably more complex, equations. Probably the most elaborate and possibly the most exact of all economic-lot-quantity formulas is the mathematically involved treatment termed Raymond's formula, developed at the request of the American Society of Mechanical Engineers. An example of how this formula can be applied is found in the *Production Handbook*.[4] The example omits, for very obvious reasons, the rather complex steps by which this formula is derived.

Suppose a screw-machine job is to be done; with the following as data, what will be most economical lot quantity?

P = 2,000 pieces per day, rate of production

Y_a = 1,500 pieces per day, average sales demand

$F = D + G + O + T + S$ = cost of drawing + planning + ordering + tooling + machine set-up = \$100 + \$25 + \$10 + \$250 + \$30 = \$415

[4] Alford and Bangs (eds.), *op. cit.*, pp. 101–102.

c' = Unit of manufacturing cost, $m + l + o$ = material + labor + overhead = \$.005 + \$.02 + \$.015 = \$.04

i = Interest earned on capital invested = 25% for 300 days = .25/300 per dollar per day

k = ½ = stock coefficient

n = 10 = number of batches

c'' = Average unit value of each batch = $m + \frac{1}{2}(l + o)$ = \$.005 + ½(\$.02 + \$.015) = \$.0225

k_p = c''/c' = \$.0225/\$.04 = \$.563

v = \$.10 per cu. ft. per year, value of storage space per unit = \$.10/300 per day

B = Cu. ft. occupied per unit (assume 100 pieces go in a 1 ft. × 6 in. × 6 in. box) = (1 × ½ × ½)/100 = .25/100 cu. ft.

a' = Time factor for batch production = $(1 + a_1 n - a_1)$. Let $a_1 = t_1/t'$ = .20, where t' = process time first batch and t_1 = process time first operation for one batch. Then $a' = (1 + .20 \times 10 - .20) = 2.80$

$$Q = \sqrt{\frac{FPY_a}{c'i\left[kP - Y_a\left(\frac{1 - \frac{1}{n}}{2}\right)\right] + c'iY_a\frac{k_p}{a'} + vB\left[P - Y_a\left(1 - \frac{1}{n}\right)\right]}}$$

$$= \sqrt{\frac{415 \times 2{,}000 \times 1{,}500}{.04 \times \frac{.25}{300}\left[\frac{2{,}000}{2} - 1{,}500\left(\frac{1 - \frac{1}{10}}{2}\right)\right] + .04 \times \frac{.25}{300} \times 1{,}500 \times \frac{.563}{2.8} + \frac{.10}{300} \times \frac{.25}{100}\left[2{,}000 - 1{,}500\left(1 - \frac{1}{10}\right)\right]}}$$

$$= \sqrt{\frac{1{,}245{,}000{,}000 \times 100}{.0033\,[325] + .0033\,[302] + .000083\,[650]}}$$

$$= \sqrt{58{,}650{,}000{,}000} = 242{,}300 \text{ pieces, economic production lot}$$

or $$\frac{242{,}300}{2{,}000} = 121.2 \text{ days' production}$$

Use 122 days' production.

Though giving exact computations, this formula is somewhat complex for ordinary purposes.

Assuming the following modifications, $P = 3{,}000$, $Y_a = 2{,}000$, $F =$ \$500, and that, for simplicity in illustration, all other pertinent factors remain constant, determine the new economic production lot.

QUESTIONS

1. Is there any basic difference between this and the more commonly used formula?
2. Compare the various terms in this and the $Q = \sqrt{2YP/CU}$ formula.

3. Under what circumstances might Raymond's technique be preferable?
4. Is the injection of the average daily sales demand a logical step?

ILLUSTRATION 3. Standardization in Relation to Inventory and Production Control

The following item, although distinctly related to standardization and simplification, as described in Chapter 4, is also very pertinent to the topics of procurement and production planning and control.

The massive quantities of materials requisite to the winning of World War II necessarily meant numerous infractions of sound management practices for reasons of expediency and exigency. However, questionable practices justifiable in the state of urgency or crisis cannot be so readily condoned during times of peace. In the interests of organizational better housekeeping, the Pentagon, prodded by several congressional committees, embarked upon a tabulation of the goods purchased or produced by the Armed Services. After ten years of study and an expenditure of $300 million, the count was completed. The final listing showed that 3,128,613 different items comprised the combined inventories.

Some interesting differences as to specifications were brought to light by this study. For example, it was discovered that the Army and Marine Corps preferred to have the slab bacon they purchased smoked 42 hours. The Navy insisted on only a 24-hour smoking.

Among the numerous other instances of variance as to specifications was the matter of height of heels on the shoes of women in the service. The Navy set 1 inch as the height of heels for WAVE shoes. The Army added an extra half inch, so that WACS wear 1½-inch heels. While on the subject of shoes, the committee found that 3,480 separately listed shoe styles were included in the combined Armed Services' inventories.

In a specific instance, it was discovered that the Army repair depot at Stuttgart, Germany, had a supply of 62,000 pounds of linseed oil unused for quite some time while three other Army commands and other military units in Germany continued purchasing linseed oil at a Munich depot. A supply of about 350,000 pounds of nails was similarly located, occupying a large storage space, while nearby commands continued their independent purchasing of more nails.

These and comparable examples, while seemingly incidental when compared with a total materials inventory of approximately $1,700 million, are nevertheless estimated to total nearly a half billion dollars worth of excess stocks. In addition to the purchase price, annual charges should be added for warehousing, deterioration, handling, protection, etc.

The committee stressed that some variance was inevitable. It also pointed out that long debate and costly investigation on minor matters would be senseless. Nevertheless, it emphasized the absolute necessity for more standardization, more rigid specifications, better procurement practices, an up-to-date inventory record-keeping system, and the value of sound planning and control relative to the handling, processing, issuance, and use of all goods needed for defense purposes.

QUESTIONS

1. What are the principal ramifications of standardization and simplification which affect the basic principles and practices incident to inventory and production control?
2. Would you recommend the application of economic-ordering lot-size formula to this phase of military affairs?
3. How might Gantt charts be useful in this case?

ILLUSTRATION 4. Mueller Brass Company[5]

This illustration outlines the procedure by which the Mueller Brass Company, Port Huron, Michigan, cut its excess production hours from 17.5 to 1.2 per cent of the "best" production time. The entire process is founded upon the premise that production control can be effectively used to schedule production, predict delivery, and keep costs at a minimum, only if adequate pertinent facts are available. These basic facts must be arranged in an orderly fashion so that proper inferences can be made. The Mueller Brass Company uses four types of reports relative to this phase of production control.

Exhibit 14-8. Departmental-load Report

Department	Departmental load					
	Unit	Produced	Added	As of today	Per cent plus or minus	Weeks at present rate of production
Automatic	Shift	1,488	1,942	12,676	+ 3.7	9
Brass shop	Hours	7,205	11,396	92,691	+ 4.7	13
Rod mill	1,000 lb	3,641	3,441	16,902	− 1.2	5
Tube mill	Pounds	688,147	575,485	4,957,418	− 2.2	7
Assembly	Pieces	104,352	193,731	983,686	+10.0	9

The departmental-load report indicates the scheduled work in various units, as shown in the second column of Exhibit 14-8. The next

[5] Adapted from E. Schleusner and M. W. Maddox, "Production Control Cuts Schedule Losses," *Factory Management and Maintenance*, vol. 114, no. 3, McGraw-Hill Publishing Company, Inc., New York, March, 1956, pp. 134–135.

column records the units produced during the specific period. The load "added" column refers to new orders scheduled for the respective departments. The summation is indicated in the load "as of today" column, which measures the backlog of scheduled orders. The figures referring to the percentage change in the orders on hand can be very useful for both planning and production purposes. Finally, converting the quantities comprising the load "as of today" into an estimate of the work on hand at present rates of production provides a very necessary objective means for systematic control of operations.

Exhibit 14-9. Compliance Report

	Percentage of compliance to weekly schedule, week ending					
	7/4	7/11	7/18	7/25	8/1	8/8
Automatic	93	93	99	95	94	94
Brass shop	92	92	90	90	93	89
Brass shop bldg. No. 4	95	92	84	81	89	95
Rod mill						
Ext	100	100	100	89	89	87
Comp	95	91	92	98	95	97
Tube mill	97	97	93	98	94	86
Plant average	88	86	89	90	89	87

The compliance report, issued biweekly, measures performance in terms of the prescribed schedule. Failure to meet schedules has obvious repercussions. Consequently, the Mueller Brass Company insists that whenever a department has less than 90 per cent compliance with schedules, the departmental supervisors must indicate the causes. This strict accountability focuses attention upon prompt elimination of production disrupting factors. In some instances where failure to meet schedules was due to unrealistic planning, unearthing the causes should lead to improved planning and better performance. From the Mueller Company's experience, it appears that the major reasons for poor compliance records stems from tool failure, absenteeism, and machine breakdowns. Recognition of these and any other major production disturbing elements should lead to corrective action. For example, in this company the number of down machines was drastically reduced by concerted effort from an average of nearly 15 per week to about 3 per week. The compliance report also provides a means for spotting chronic trouble areas. Persistence in poor compliance records can indicate the need for a radical transformation of personnel, methods materials, or equipment within the chronically lagging component.

The third report, that on delinquent orders, is also compiled biweekly. This report brings to attention even more forcefully those areas which are lagging. The over-all failure to meet schedules on an order basis is also summarized. At Mueller Brass, when this system of reporting was first installed orders behind were at a surprisingly high figure of 529. After diligent application of corrective measures, the number was reduced to less than 100. Exhibit 14-10 shows total lagging

Exhibit 14-10. Delinquent-order Report

Commodity	Order compliance during week	On time	Less than 2 weeks behind	Over 2 weeks behind	Total behind this week	Total behind last week
Brass forging	40	30	8	2	16	15
Forge machine	26	20	5	1	9	12
Automatic only	21	17	2	2	7	5
Automatic brass shop	5	5	0	0	0	0
Casting	1	1	0	0	0	3
Tube bends	15	9	2	4	1	3
Assemblies	10	7	2	1	9	5
Alum forge	3	1	1	1	7	5
Rod	147	119	19	9	36	23
Total	268	209	39	20	85	71

orders numbering 85 for the week studied and only 71 delinquent orders during the previous week. In addition, this type of report permits comparison of total orders processed with delinquent orders. The ratio of long-overdue to total orders can also be helpful in appraising the company's ability to expedite scheduled work.

Exhibit 14-11. Trouble Sheet

Customer	S.O. no.	Part no.	Amount on back order	Promised delivery date	Weeks		Remarks
					In dept.	Total	
Stock	553	W-40332	2,000	8/1	2	2	Delayed
Stock	1838	W-1009	80,000	8/1	2	2	To be staked
Stock	1842	W-1019	30,000	8/8	1	1	To be burred
Stock	2714	W-1038	4,000	8/8	1	1	To be burred

The fourth in this series of reports is a list of individual orders which have missed the time set for completion. Since each order is carefully numbered, it is easy to identify and to track. When an item

appears on this list, production control follow-up men initiate action. If, despite such action, an item continues on this trouble sheet for a period of four weeks, the matter is called to the attention of the vice-president of production or his assistant. In the rare instances where a delay continues for eight weeks, the executive vice-president takes charge.

Exhibit 14-12

	7/13–7/26 1953	1954	10/3–10/21 1955
Actual time taken	14,395	158,488	19,462
Best production time	12,229	153,796	19,230
Extra time used	2,166	4,692	232
Estimated hours saved	0	22,222	3,133
Per cent extra time	17.5	3.0	1.2

The results of this careful control of production indicate a drastic cut in the extra time used in excess of the best production time from 17.5 to 1.2 per cent. This conclusion was arrived at after careful study over a two-year period. Three samples of these studies are listed in Exhibit 14-12. It should be noted that because of the improved production control, a significant portion of productive time is saved.

QUESTIONS

1. How is the exception principle applied in this case?
2. What is the value of knowing how many weeks' backlog of orders exists?
3. If a specific department consistently has a compliance report of 100 per cent, does this necessarily mean that all is in order?
4. Evaluate the compliance report shown in this illustration.
5. What are the limitations of using the unit of total number of orders as is done in the delinquent-order report?
6. Is Mueller's insistence upon explanations from supervisors when the compliance report shows figures below the 90 per cent level realistic?

ILLUSTRATION 5. "The Case of the Missing 100,000 Paper Clips" [6]

"I say, Reginald, can you spare a paper clip?"

If he took part in a British survey conducted by the editors of Lloyds Bank to find out what happens to 100,000 paper clips, Reginald probably can't—spare one, that is.

A precise 100,000 clips were taken as a sample (at Chicago prices that's about $48 worth). The findings, as reported in the *Chicago Daily Tribune's*

[6] *American Business,* April, 1958, p. 34.

"A Line O'Type or Two" column, show that 14,163 were twisted out of shape or broken by persons not fully concentrating while talking on the telephone.

Paper clips averted 7,200 serious tragedies, filling vacancies suddenly created by a snapped button or hook on garters and other items of human rigging.

The most surprising figure in the lot is 19,143. The number of clips—almost one out of five—was used as stakes in card games. The only explanation for this figure, according to the newspaper, is that it reveals for the first time exactly what goes on in banks after the doors close at 3 P.M.

Sanitation absorbed quite a few. To be exact, even at the cost of delicacy, 5,308 were used to clean fingernails; 5,434 to pick teeth; and 3,169 to clear pipe stems. (For cleaning ears, Britons use matches, which explains why lighters are not too popular over there.)

The statisticians suggest that at least 30,000 clips were dropped on the floor and left for the cleaner to sweep up. The clips thus went into rubbish bins and left no remnant for the counters to count.

The same thing is true of the final category. The statisticians swear that the remainder was used to clip sheets of paper together. The exact number here also is incalculable, even with an electronic brain, because the clipped papers went into letters or files and vanished from the bank's ken.

QUESTIONS

1. What inferences, in the sphere of inventory and production control, can you draw from this facetious illustration?
2. Assuming this was intended as a serious survey, what imperfections in statistical technique can you spot?
3. If a comparable lack of information as to intermediate and final use characterized major consumer and producer goods, what obstacles can you see to the effective use of scientific production planning and control?

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CHAPTER 15

Cost Control

DEFINITION AND DESCRIPTION

The concept of cost is subject to varying interpretations. This variability is the consequence of cost being associated not only with monetary payments but also with the relinquishing of utilities and rights. The latter aspects inject psychological and sociological considerations into what is too frequently assumed to be an economic matter. Invariably cost is a payment of some sort, generally in exchange for some desired object or service. This payment implies not only changing ownership but also forgoing all the rights associated with the good or service exchanged. Forgoing of rights and benefits constitutes cost.

Since this text is primarily concerned with those costs fundamental to business and industrial activity, only a fleeting commentary on the nonmonetary aspects of cost will be ventured. Presumably a decision maker must be aware of such costs. If a particular course of action proves to be the cheapest in terms of actual cash outlay, it might still not be the best course to follow. This is the case when a significant segment of the organization is perturbed and even demoralized by the action. There is no question about the deleterious consequences of poor morale and related negative reactions. Although classified as subjective forces, they do invariably manifest themselves in objective reactions. Conversely, the benefits accruing from effective performance

cannot always be equated in dollars-and-cents terms. In many instances psychic income more than compensates for lower pay. This is especially the case where the participants have attained an income level at which the marginal dollar offers minimum satisfaction. Recognizing the significance of both nonmonetary costs and benefits, the decision maker will, despite the greater complexity of his problem, in all likelihood do a more competent job.

Kinds of Costs. One of the most concise classifications of cost distinctions is that presented by Dr. Joel Dean in his well-known *Managerial Economics.* Exhibit 15-1 lists and compares 20 different types

Exhibit 15-1. Classification of Cost Distinctions

Dichotomy		Basis of distinction
Opportunity costs	Outlay costs	Nature of the sacrifice
Past costs	Future costs	Degree of anticipation
Short-run costs	Long-run costs	Degree of adaptation to present output
Variable costs	Constant costs	Degree of variation with output rate
Traceable costs	Common costs	Traceability to unit of operations
Out-of-pocket costs	Book costs	Immediacy of expenditure
Incremental costs	Sunk costs	Relation to added activity
Escapable costs	Unavoidable costs	Relation to retrenchment
Controllable costs	Noncontrollable costs	Controllability
Replacement costs	Historical costs	Timing of valuation

SOURCE: Joel Dean, *Managerial Economics,* Prentice-Hall, Inc., Englewood Cliffs, N.J., 1951, p. 271.

of costs and indicates the basis for distinction between various "pairs" of costs.

A detailed description of each of these costs would be tedious and time-consuming. Consequently, only a few of the more commonly used terms will be defined at this point.

1. Opportunity costs arise when a decision maker considers the results of a chosen course of action as compared with the results that might have been realized had some other course of action been selected. This type of analysis is extremely important where limited factors of production make it impossible to embark upon a variety of ventures. Thus the chosen course of action, since it drained available resources and prevented recourse to alternatives, is a prime factor in the generating of cost. While extremely important for decision making in the selecting of the best possible course of action, opportunity costs do not appear on the corporate records because, in

essence, they are fictional costs. Since they are not acceptable for accounting purposes, opportunity costs, unfortunately, are too often overlooked.

2. *Outlay costs* represent actual payments and consequently form the basis for financial, operating, and accounting records. In the control of an industrial organization, it is this type of cost which is of paramount importance because it provides a factual basis for comparison of performance. Nevertheless, there are some serious limitations associated with outlay costs. Inflationary and deflationary forces are not always properly reflected in records based on these costs. Then too, there is not always a perfect correlation between the cost and the real worth of the commodity or service in question.

3. *Out-of-pocket cost* bears some similarity to outlay cost in that it represents an actual payment made to someone. The cash position of the company is immediately affected by this type of payment.

4. *Book costs* are less immediate and do not necessarily involve an outlay of cash at the time such costs are computed. Depreciation and depletion charges are typical of this type of cost.

5. *Incremental cost,* as the term implies, refers to increases in cost attributable directly to changes in the level, type, or tempo of activity. Doubling the rate of output will evidently mean an increase in total costs. That which is added by such action to total cost can be called the extra or incremental cost.

6. *Sunk costs* are, in some respects, fixed in character since they are not affected by fluctuations in the rate of activity. For example, rental fees, insurance premiums, most salaries, and even certain taxes tend to remain constant regardless of the rate of capacity utilization.

7. *Constant, or fixed, costs* resemble sunk costs in that they are nonreducible over a specified period of time. Strictly speaking, there is no such thing as an absolutely fixed cost. The entire notion is relative. What is termed "fixed cost" retains this fixity characteristic only as long as certain premises as to time and usage perdure. If, for example, the usage factor is substantially revised upward, then additional fixed-cost items, such as equipment and indirect labor will be needed. This increase, however, will tend to be in steps and will pertain to ranges of productive potential. It should be noted, at this point, that the concept of fixity as to costs pertains only to the totality of such costs over a specified time period. These same costs, when translated into costs per unit, actually acquire a characteristic of variability. In other words, constant costs are fixed in their totality but on a unit basis vary inversely with the number of units involved. For example, an annual rental charge of $1,500 will probably remain unchanged

during the term of the lease. If 10,000 units were produced during that particular year, then the proportionate rental charge applicable to each unit of product equals $1,500/10,000 = $0.15. However, if output were increased to 15,000 units, then this "constant" charge would decrease to $0.10 per unit.

8. *Variable cost* includes a wide variety of charges which vary directly with the quantity of product. In some respects variable costs are very similar to incremental and out-of-pocket costs. These designations are sometimes used interchangeably. This variability is always associated with specific time intervals and stated capacity factors. In many instances these variable costs tend to change with modifications in the capacity factor. Thus the variable costs might be relatively high in the extreme lower ranges or the extreme higher ranges of capacity utilization. Since such variance is both difficult to measure and to explain, variable costs are generally expressed as an average of such costs.

In contrast to constant costs, which remain fixed in totality but vary unit-wise according to the number of units processed, variable costs tend to remain fixed per unit but vary as to the sum of such costs. For example, if variable costs averaged $0.28 per unit, then this cost per unit remains unchanged regardless of volume fluctuations. If 10,000 units were processed, then total variable costs would amount to $2,800. If the output were increased to 15,000 units, variable costs would jump to $4,200. The variance in the total variable costs is directly proportionate to the change in product volume.

In this simple example total costs would be expressed as follows:

	Units processed 10,000	15,000
Total fixed cost	$1,500	$1,500
Total variable cost	2,800	4,200
Total cost	$4,300	$5,700

Following the same pattern unit costs would be calculated as follows:

	Units processed 10,000	15,000
Fixed cost per unit	$0.15	$0.10
Variable cost per unit	0.28	0.28
Total unit cost	$0.43	$0.38

In this instance, while total costs rise to $5,700 with the increased quantity processed, unit cost declines from $0.43 to $0.38 per unit. The significance of this decline should be obvious. However, the diminishing importance of fixed cost per unit as quantity is expanded has specific limitations. If, for example, increasing output beyond 15,000 units would entail duplication of facilities resulting in another investment of $1,500, then obviously the cost pattern would be modified significantly.

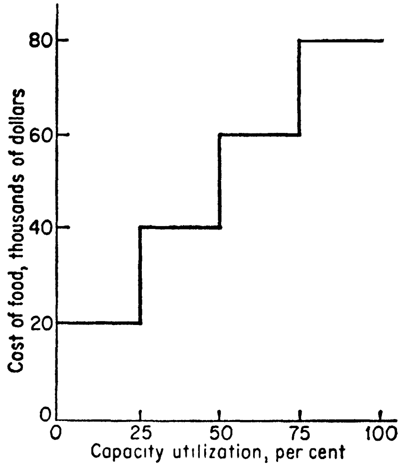
9. Semivariable costs cover a wide variety of costs. On the surface, the distinction between constant and variable costs might seem to be an adequate means for differentiating all costs of organization and production. However, the individual business unit and the specific industry frequently find it imperative to make modifications to meet particular environmental conditions. Consequently, there is no uniformity as to where fixity ends and variability begins for most costs. The result is a category termed semivariable costs. There is no set behavioral pattern for this category. Some will exhibit a rigid constancy up to a given production point and will then abruptly, and at a single point, jump to a higher level. Others will remain fixed over a given range of activity but will then become variable over other activity ranges. Some incorporate elements of both fixed and variable costs. For example, purchases of food by a restaurant are not made on a hand-to-mouth basis in direct correlation with customer demands. Specific ordering points are set up for certain types of goods. If the nature of the food, storage facilities, costs, etc., necessitate stocking with enough raw materials to accommodate approximately 25 per cent of the restaurant's practical capacity, then this semivariable cost would remain fixed between the zero and the 25 per cent capacity range. Assuming further orders likewise cover comparable needs, then these costs assume a step pattern as shown in Exhibit 15-2.

If this is the strategic cost in the business venture, it is important that capacity utilization be geared to just below one of the step-up points. The significant difference, for example, in total costs for this item between the 49 and 51 per cent capacity-utilization points is evident. This policy-making consideration, however, loses significance if the remaining cost patterns more than offset the step-increment pattern.

This brief description of nine fundamental types of costs is by no means a complete treatment of the subject. There are so many complicating factors that a prudent decision maker must invariably dedicate much more time to acquaint himself with the numerous ramifications and shades of difference relative to costs. The purpose

of this chapter is not to give the would-be administrator a thorough grooming in all aspects of cost analysis. However, it is presumed that this peripheral contact will provide at least a minimum substantial base for effective decision making.

Exhibit 15-2. Step Progression in Fixed Costs



TECHNIQUE 1. Budgetary Control

A budget is simply a plan of action showing how available resources are to be allocated for future use. It should be obvious that in preparing a budget numerous decisions must be made. Among the considerations pertinent to decision making in the sphere of budgeting are the following:

1. The loci of responsibilities
2. The time factor
3. The constant elements
4. The strategic variables
5. The degree of control over the variables
6. The degree of dynamism affecting the situation
7. The probabilities of success with each possible allocation of resources
8. The estimated optimum budget
9. The rigidity or fluidity of this estimate
10. The sequence and feasibility of alternate courses of action

In every instance sound budgeting begins with proper record keeping. Lacking adequate factual information, the budgetary officers tend to express opinions rather than to make sound scientific estimates. A mass of data, however, can be without meaning unless there is an

intimate acquaintance with and a comprehension of the observed phenomena. The records must provide relevant facts. The information must not be so old as to be meaningless. Then too, the information must be tempered in the light of technological trends.

It was emphasized in a preceding chapter that the probability of occurrence of a predicted event is closely correlated with the span of time involved in the prediction. Long-run estimates invariably tend to be less accurate than short-run predictions. This reasoning is directly applicable to budgets which, in effect, are simply decisions as to the best possible distribution of resources, assuming that certain conditions will most likely prevail. Despite this inverse relationship between accuracy in prediction and the span of time, it is important for budgeting purposes that the time interval be sufficiently long to justify the need for budgeting. If the periods are excessively short, there is a minimum need to initiate the relatively costly process of collecting and analyzing facts, drawing up the budget alternatives, selecting the best allocation of resources, and then putting this plan of action into effect. For extremely short-run estimates, the immediately preceding experience can generally provide as accurate an estimate of need for the following period as can be obtained from more elaborate estimating procedures. It should be assumed, then, that a budget period should be of sufficient length to allow for the interplay of important managerial problems of policy and strategy.

It should be obvious that the over-all corporate budget is the product of numerous variable items. The major, or master, budget is also a composite of many lesser or component budgets. Recourse to what might be termed microanalysis helps simplify the budgeting procedure significantly. Generally, if the unit for which estimates are being made is not too large, the budget officers can isolate one or a few of the more important factors directly affecting the basic operation. If the single or several important elements exert so great an influence that they become strategic factors, then budgeting can be simplified by a process of direct correlation.

The basic purpose of all industrial budgeting is to secure control over operational activities. Through this control, if it is effective, the organization obtains a measure of stability. Lacking such stability the organization follows a very precarious course which can eventually lead to deterioration in competitive position, financial embarrassment, and in some cases to bankruptcy. It is important to note that stabilization is not synonymous with *status quo*. Actually, we are here concerned with what might be termed "fluid-type stability," wherein modifications and adjustments do occur in a nonprecipitous fashion

as industrial dynamism demands. Stabilization in this context might appear to be a contradiction in terms. However, on deeper study it should be obvious that in the industrial sphere there are no absolutes —all concepts, situations, and things are relative and change with the passing of time.

Lacking sound budgetary procedures, it becomes practically impossible for a management to plan its affairs. Modern industrial organizations, because of their complexity, need considerable time to make even seemingly slight adjustments in their tempo of activity. On the surface it might seem to be an incidental decision to modify the production pattern for a given machine or department. However, such change generally involves a multitude of decisions as to raw materials, goods in process, personnel, equipment, etc. The more complex the situation, the more time must be given to the decision as to the course of action to be followed. Revamping plant layout, purchasing new equipment, introducing a new product, changing the product mix, financing new ventures, and similar problems entail a great deal of budgeting.

Kinds of Budgets. As has been implied, any future activity involving the use of equipment, space, money, people, goods, etc., can be the subject of budgeting. In industry, however, there are several areas in which this function assumes major proportions. In these areas relatively standard procedures have been evolved for more effective budgeting.

1. Sales Forecasts. Theoretically, all budgeting centers around the estimate of future sales. The marketing of a product, however, is affected by so many factors that accurate prediction is extremely difficult to make. Because of the inherent hazards, there are many individuals who attach minimum importance to sales forecasting. Nevertheless, it seems logical to infer that if certain conditions tend to expand or deflate sales, knowledge of and the ability to control these forces should result in better predictability of future sales. Once sales forecasting is given a substantial base, the budgeting aspects so intimately associated with the forecasting of sales can be more effectively utilized. While this is not the appropriate place to analyze the many ramifications of business-forecasting theory and techniques, it might be helpful at this point to list the forecasting procedures as summarized by Dauten:[1]

1. Group the products into classes with about the same demand characteristics.

[1] Carl A. Dauten, *Business Fluctuations and Forecasting,* South-Western Publishing Company, Cincinnati, 1954, p. 466.

2. Study the trend of sales of each forecasting group. Account for this trend.

3. Compare trends with those of gross national product or disposable personal income and with the industry trend.

4. Find a relationship to a logically related general economic variable, nationally if sales are on a national scale, or by states or regions in which sales are made. Explain all deviations from the general pattern of relationship.

5. Find the relationship of sales to industry sales. Account for the general pattern and for any deviations from it.

6. Using past relationships, general business and industry forecasts, and a knowledge of all qualitative factors in the present situation, project company sales for a year ahead by product groups.

7. Calculate the seasonal pattern. Check to see if there are any factors that might cause it to change. Put the annual forecasts on a monthly and a quarterly basis.

8. Study all plans for sales promotions and the like and determine their probable effect on sales.

9. Obtain estimates of sales from salesmen by territories and major customers and revise the forecast, if need be, in the light of this information.

10. Have a committee of top management review the forecast and adjust it if they see fit.

11. Review the forecast at least quarterly. Continually study factors that might make it advisable to change the forecast.

12. Review all past forecasts and determine, if possible, the reasons for error.

These steps or slight modifications of them provide a logical sequence through which not only sales forecasting but every type of budgeting should proceed.

2. *Production Budgets.* This phase of budgeting is intimately associated with production control. As is pointed out in Chapter 14, once reliable estimates of demand for the product are available, then manufacturing facilities can be activated to attain desired rates of output. The rate of output, in addition to depending upon the sales potential, is conditioned by the availability of equipment, personnel, materials, adequate financing, etc. Once all these conditioning forces have been properly taken into account, then a production budget can be prepared for the period of time in question. A very simple illustration of a production budget for the making of air conditioners might take the form shown in Exhibit 15-3.

Exhibit 15-3

Month	*Scheduled production units*	*Month*	*Scheduled production units*
January	1,000	July	1,500
February	1,100	August	800
March	1,300	September	500
April	1,600	October	500
May	2,000	November	500
June	2,100	December	800
		Total	13,700

It should be noted that there is a distinct correlation between the production budget and the weather. While this correlation cannot be termed direct, once the anticipation factor is taken into account, fairly reliable production budget figures can be projected. Then too, this particular budgetary approach has not made any provision for the more detailed planning paramount to actual production. However, the budget having been set at an estimated 13,700 units, assuming a no-inventory situation, and allocation of production orders by months having been completed, detailed budgeting can begin. For example, as a concomitant of the 1,000-unit allocation for January production, it is possible to determine the precise quantity of materials needed, the components to be manufactured, the parts to be purchased, the man-hours of direct and indirect labor required, and the essential quantities and qualities of all other productive factors. In turn, these can be allocated by department, by machine, or even per man. The one-month period can be subdivided into week, day, or hour intervals. In substance, then, the production budget and its adjuncts serve as indispensable tools by means of which decision makers can perform more effectively.

3. Inventory Budgets. The preceding illustration of the production budget was not necessarily a parallel of the sales budget. If there is a significant variance between sales and production budgets, then obviously there will be need for an inventory budget to bring the situation into balance. Adding a sales forecast to the production budget and injecting a few assumptions as to beginning inventory into the previous example yields the form shown in Exhibit 5-4.

On the surface it would appear that there are six or seven months when the inventory budget indicates rather excessive reserves. However, even a glance at the sales budget should be sufficient to convince

Exhibit 15-4

Month	Sales forecast	Production budget	Inventory
Beginning inventory			1,200
January	100	1,000	2,100
February	100	1,100	3,100
March	200	1,300	4,200
April	800	1,600	5,000
May	2,300	2,000	4,700
June	3,500	2,100	3,300
July	3,200	1,500	1,600
August	2,000	800	900
September	900	500	
October	300	500	200
November	100	500	600
December	100	800	1,300
Total	13,600	13,700	

one that gearing production directly to sales would generate a set of new, and possibly more complex, problems. The question of inventory budgeting is closely dependent upon prevailing industry and company practices, the speed with which the production departments can put units together, the urgency with which rush orders must be met, the danger of obsolescence, the level of carrying charges, and similar considerations. The situation is far more perplexing when dealing with high-cost goods which are subject to sudden style or technological change. The inventory budget is, to some extent, closely correlated with the concept of economic lot size. This topic was discussed in Chapter 14. Obviously, the size of the lot manufactured or purchased, together with the rate of product use, will serve to determine the inventory quantities. Other considerations include procurement or lead time, quantity discounts, storage facilities, transportation requirements, and market conditions. If, for example, these and related conditions result in a significant lag between the sales order and the receipt of the product by the customer, then a safety factor must be devised. The size of the safety stock will depend upon the costs entailed and the desirability of maintaining sound customer relations. In such a case the inventory budget must provide for a margin of safety. In the air-conditioner case, assuming that 200 units will provide adequate protection, only the month of September would be affected. The production budget would then reflect this safety margin, probably by a comparable increase in the September production quota.

4. Expense Budgets. In all business ventures it is fundamental to assume that every action will have reactions, in terms of desirable results together with certain costs. The expense budget attempts to anticipate, in an orderly sequence, the probable expenditures associated with the scheduled activities. Through the medium of this type of budget, the manager can readily note whether or not his resources are adequate for any given period of time. Without this control tool it is very easy for the decision maker to plan and approve activities which would require resources beyond those possessed by the organization.

Expenses are generally classified as (1) manufacturing expenses, (2) selling expenses, and (3) administrative expenses. This conventional classification can, in turn, be subdivided as deemed necessary. For example, a direct-labor budget is generally used in conjunction with the manufacturing expense and the production budgets. This interrelationship of budgets is easily accomplished by the simple expediency of converting units of product, man-hours, etc., into monetary terms. Actual labor costs per hour or an average rate per hour can be used to translate man-hours into monetary labor cost. Similarly, product volume can be multiplied by the average unit selling price or cost to obtain value units for budgetary purposes when necessary.

Expense budgets apply not only to the labor factor but to every ingredient essential to the fulfillment of the organization's objectives. Consequently, expenses associated with direct materials, overhead, capital expenditures, and even taxes, should appear in budget form. The merit for control purposes of such orderly presentation should be evident.

5. Variable and Fixed Budgets. Analyzed from a somewhat different viewpoint, budgets can be categorized as variable or fixed. The latter assumes that sales and production can be anticipated within very close limits of approximation. Such precision in estimating would permit the setting of rather definite subsidiary budgets. There are numerous advantages which follow from the valid application of fixed budgets. The decision maker can plan and implement his plans far more effectively when he has a fairly dependable estimate of the next period's sales potential. Assuming the possibility of only slight variance from the estimate, the planner can then draw up very specific budgets as to quantity and quality requirements of components, materials, manpower, money, etc.

On the other hand, the vagaries of dynamic business tend to make definitive estimating very hazardous. Consequently, many corporations prefer to use variable budgets. This version of budgeting is based

upon an analysis of the probabilities as to various sales levels anticipated for the next fiscal period. Estimates are then made for the sales potential assumed most likely to occur. However, in addition to using this as the anchor, considerable latitude is permitted by determining two or more other levels of sales which have a high likelihood of attainment. In some cases a range of probabilities is calculated, with distinct points of probable maximum and probable minimum. This type of budget presumably has the advantage of needing no exact estimate of future sales since adjustments in all pertinent factors and subsidiary budgets can be accomplished by the use of multipliers.

Variable budgets, while useful in situations characterized by considerable uncertainty, have been condemned because they are rather indefinite. Hence the decision maker is handicapped. Instead of plotting a direct course of action, the decision maker must, using variable budgets, proceed with far less assurance. Consequently, some authorities believe that fixed budgets should be used whenever possible. In some areas, particularly where demand patterns fluctuate violently, variable budgets are defensible. Also, organizations without long experience in reliable forecasting might prefer the flexibility of the variable budget.

In summary, budgeting is synonymous with control of resource expenditure. This type of planning and control can be useful at every organizational level. It is of paramount value for top-level decision makers. Unless an organization's resources are channeled in orderly sequence, in the proper direction, there is a strong possibility that the maximum attainment will not be realized.

TECHNIQUE 2. Break-even-point Analysis

In nontechnical terms the break-even point is that juncture where income and costs are exactly in balance. Thus there is neither profit nor loss from operations. At this equilibrium point an organization is certainly better off than one whose records show a loss. However, as every prudent manager knows, the break-even point merely indicates the minimum operating level below which it is dangerous to fall. As performance veers toward this no-profit point, corrective measures should be taken to cut costs, increase output, or raise prices.

The break-even point frequently is viewed as a percentage of capacity. For example, a break-even point of 62 per cent means that when the plant or corporation reaches a performance level equal to 62 per cent of its attainable capacity, income exactly balances costs. It should be noted that as operations become more and more mecha-

nized the break-even point tends to move ever closer to 100 per cent. The higher the break-even point, the less flexibility possessed by the organization. Thus one of the consequences of mechanization, and particularly of automation, is the inevitable raising of the break-even point to levels which make breakdowns, poor scheduling, and other deterrents to capacity utilization extremely costly. Break-even points also tend to be higher in continuous- as versus intermittent-type operations.

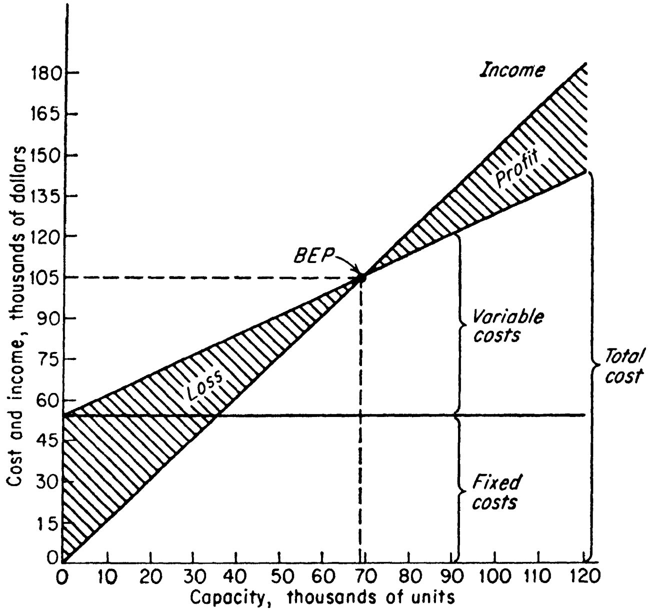
The basic components of a break-even chart include a vertical scale measuring sales and cost in monetary units and a horizontal scale indicating units of product. Since it is generally assumed that the selling price will remain uniform, the sales line is at a 45-degree angle with the horizontal and vertical lines.

An assumption is made in break-even analysis that some costs will vary directly with capacity utilization while other costs will not be affected in this fashion. These characteristics of costs have previously been described in the section differentiating between variable and constant costs. The break-even chart helps clarify this distinction by presenting a graphic contrast between these two basic cost categories. The most commonly used charting technique shows fixed costs as a straight line parallel to the base. Variable costs are superimposed upon this fixed base. The angle of the variable-cost line will vary directly with the relative importance of the variable costs. This top line, in addition to measuring variable costs, also represents the total-cost curve. The place where this total-cost curve intersects the income line is termed the break-even point. Exhibit 15-5 is a simple example, charting a situation where capacity is estimated at 120,000 units per month; selling price equals \$1.50 per unit; fixed costs total \$48,000 for the accounting period; and variable costs come to \$0.80 per unit.

In this hypothetical situation the break-even point, as shown on the chart, falls at approximately 69,000 units of product, which equals \$103,000 sales volume. Assuming a practical maximum capacity of 120,000 units, the break-even point equals almost 57 per cent of the attainable capacity. Until this point is reached, operations are unprofitable. The gradual tapering of the "loss" segment shows how losses tend to disappear as the break-even point is approximated. On the other hand, as the facilities are utilized beyond the 57 per cent level, profits tend to increase rapidly. Assuming an optimum situation wherein full capacity was utilized, the total profit would be maximized at \$36,000. To achieve this maximum sum, 120,000 units must be sold at an average price of \$1.50 per unit. Out of this \$180,000 revenue,

$48,000 must be deducted to meet fixed costs. In addition, 120,000 units times $0.80, or $96,000, must also be subtracted for variable costs. $180,000 − ($48,000 + $96,000) = $36,000 profit.

Exhibit 15-5. A Break-even Chart



Out of this calculation it is possible to derive a very basic and very concise formula:

$$P = I - (FC + VC)$$

where P = profit or loss
I = income, computed by multiplying average selling price per unit times the number of units sold
FC = fixed costs
VC = variable costs, computed by multiplying the average unit variable cost times the number of units processed

If, for example, 90,000 units were sold, then:

$$\begin{aligned} P &= I - (FC + VC) \\ &= (1.50)(90{,}000) - [48{,}000 + (0.80)(90{,}000)] \\ &= 135{,}000 - (48{,}000 + 72{,}000) \\ &= 135{,}000 - 120{,}000 \\ &= \$15{,}000 \end{aligned}$$

Another formula, even more concise and easier to compute, is based upon the hypothesis of a direct relationship between the break-even

point and the variable costs. Thus break-even point (*BEP*, expressed as unity, or 100 per cent) equals fixed costs (expressed in dollars) plus variable costs (expressed as a percentage of sales). All figures should pertain to maximum attainable capacity. Converted into formula structure,

$$BEP, \text{ or } x = FC + \frac{VC}{I}x$$

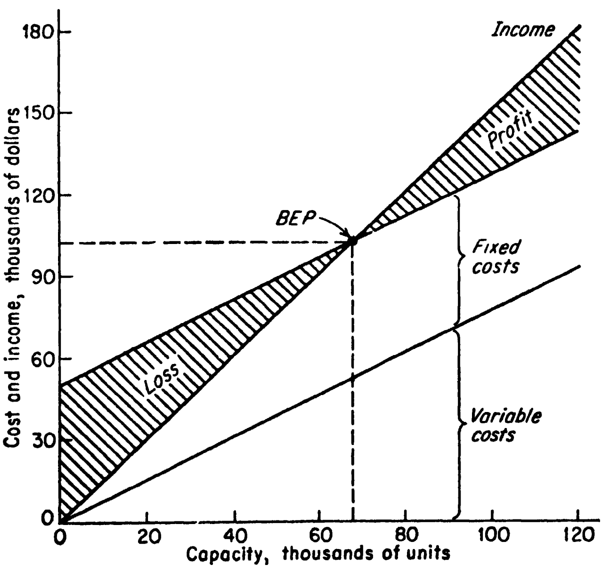
Applying these data from the preceding example,

$$\begin{aligned} BEP, \text{ or } x &= 48{,}000 + \frac{96{,}000}{180{,}000}x \\ x &= 48{,}000 + 0.533x \\ x - 0.533x &= 48{,}000 \\ 0.467x &= 48{,}000 \\ x &= \$102{,}800, \text{ or } 68{,}600 \text{ units, approximate break-even point} \end{aligned}$$

In effect, this formula is a short-cut device adequate for most approximations of the break-even point when revenue, fixed costs, and variable costs are given.

The break-even chart, as shown in Exhibit 15-5, is only one of

Exhibit 15-6. Alternate Form of the Break-even Chart



several methods for graphically expressing this concept. For example, some analysts prefer to start the variable-cost line at the apex, or zero point. Fixed costs are then superimposed upon the variable-cost line. This type of presentation presumably gives a better graphic view of the variable cost and income relationships together with the margin available for fixed cost and profit.

Numerous other variations can be made specifically if cost or income patterns vary at any point within the range being plotted. The effect of such changes is to modify the respective straight line by either a sudden step upward or downward or by a curvilinear expression. In addition, the several components of both variable and constant costs can be depicted separately in the chart. Obviously, such elaborations complicate the analysis and can easily vitiate the basic purpose of the graphic technique. Since the function of the chart is to explain the cost-income relationship in a simple fashion, undue complication must be avoided.

Another note of caution relates to the exactness with which the break-even point is calculated. Since there are so many assumptions prerequisite to the application of this technique, it would seem judicious to allow for a plus and minus variance of perhaps 2 per cent of the stated capacity. Thus in the preceding example, instead of holding rigidly to the break-even point of 57 per cent, as shown on the chart, it might be advisable to think in terms of a break-even "range" of between 55 and 59 per cent of capacity. While the range approach is less rigid and helps to account for minor errors and slight shifts in the factors, it can easily lose its meaning if the range is expanded too greatly.

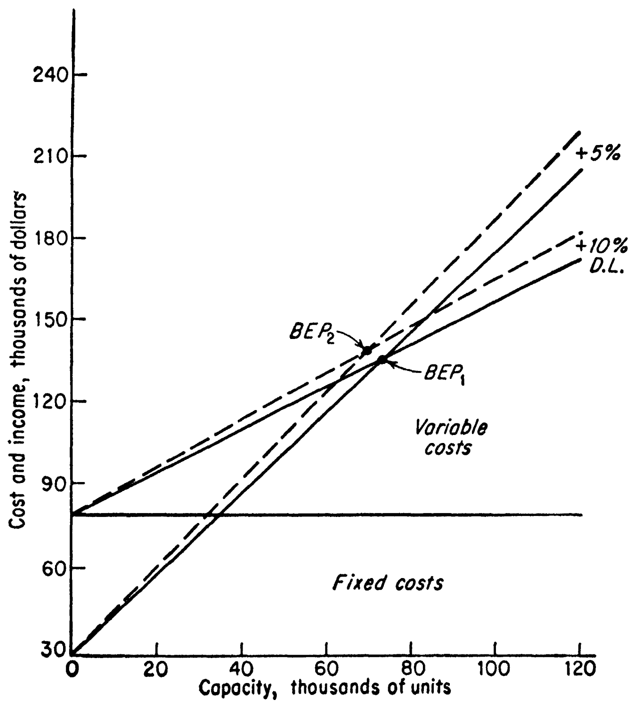
Another variation in break-even analysis is the inclusion on the chart of imminent or even hypothetical modifications in one or several of the pertinent terms. For example, management might want to know what effect a proposed 10 per cent increase in direct-labor costs would have upon profits. In this instance, variable costs would, of necessity, be divided so that direct-labor costs could be segregated. Assuming that the $0.80 per unit variable costs previously postulated included $0.30 direct materials and incidental costs, with direct labor accounting for the remainder, then a 10 per cent increase in direct-labor cost would amount to $0.05 per unit. For the maximum attainable capacity of 120,000 units, this would mean an increase of 120,000 × $0.05, or $6,000 variable expense. If no compensating increase in sales price were contemplated, then the break-even point would be adjusted upward as follows:

$$
\begin{aligned}
BEP, \text{ or } x &= FC + \frac{VC}{I}x \\
x &= 48{,}000 + \frac{102{,}000}{180{,}000}x \\
&= 48{,}000 + 0.567x \\
0.433x &= 48{,}000 \\
x &= \$110{,}850, \text{ or } 73{,}900 \text{ units}
\end{aligned}
$$

In a great many instances a sudden shift in the revenue-cost balance, such as would follow from this proposed wage increase, can have serious consequences upon operating effectiveness. If, as an illustration, current market conditions warrant only a 70,000-unit-per-year rate of operation, then the seemingly slight wage increase means the difference between profit and loss.

Assuming, as is frequently the case, that the wage increase is accompanied by a product-price increase, the situation is again modified. If the sales price were boosted only 5 per cent, then revenue expands

Exhibit 15-7. Effect of Income and Cost Changes upon the Break-even Chart



to \$189,000 at the full-capacity level. The new break-even point is computed:

$$
\begin{aligned}
BEP\text{, or } x &= FC + \frac{VC}{I}x \\
&= 48{,}000 + \frac{102{,}000}{189{,}000}x \\
&= 48{,}000 + 0.539x \\
0.461x &= 48{,}000 \\
x &= \$104{,}100\text{, or } 69{,}400 \text{ units}
\end{aligned}
$$

Similarly, a change in any of the numerous cost components or in the income account will be reflected in a shift of the no-profit–no-loss equilibrium point. It should be noted from the preceding arithmetic illustrations that the relative size of fixed- and variable-cost figures is extremely important for setting the break-even point. Low relative fixed-cost figures will provide equally low break-even points, and vice versa.

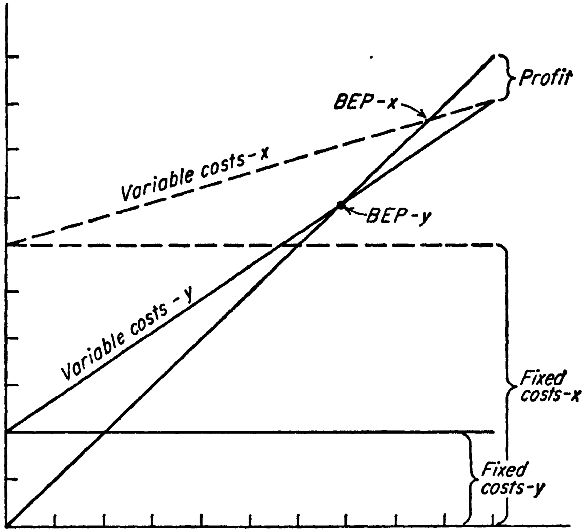
Break-even analysis can be unduly biased in cases where only one operation in a sequence is being considered. Similarly, difficulties arise when the manufacturer buys certain component parts, which are then further fabricated or assembled. In either case, recourse to the concept of value added, described in Part One, is mandatory. By using this concept, the direct materials cost, which would otherwise be rather disproportionate, could be deflated to proper size. Injection of the value-added concept into the analysis does not alter the basic structure or use of the familiar chart.

References to industry break-even points are often very misleading. For example, as recently as thirty years ago, the bituminous-coal industry was assumed to have a break-even point as low as 30 or 40 per cent of capacity. With two decades of rapid mechanization in the bituminous-coal industry, this break-even point has presumably shifted upward to approximately 60 or 70 per cent of capacity. Likewise, the iron and steel industry purportedly moved to an 85 per cent break-even level. Yet in times of stress it has been noted that such relatively high attainments tend to be fictitious. Thus in the 1958 economic slowdown, most steel-making corporations were breaking even or earning meager profits at operating levels as low as 55 or 60 per cent of rated capacity. Likewise, many coal companies have been making profits at less than the 70 per cent operating level. There are numerous reasons underlying this phenomenon. A major factor might be the elimination of high-cost productive facilities. This, together with cost trimming up and down the organizational line, means that an entirely new income-cost relationship has been achieved. Break-even

analysis is, consequently, valid in either instance. It must be noted, however, that the analysis is conditioned by different sets of circumstances.

Considering the multiplicity of variables which affect business and industrial activity, it would be very rash to postulate an optimum break-even point for all organizations or even for a major segment of our economy. As has already been implied, even in a single industry break-even points can vary widely for equally successful organizations. Exhibit 15-8 depicts two corporations, each with sales of $1 million

***Exhibit 15-8. Break-even Comparison, Companies* x *and* y**



and net profits of $100,000 but with radically different fixed- and variable-cost structures. Corporation *x* presumably expends $600,000 and $300,000 for fixed and variable costs, respectively, while corporation *y* has a $200,000 and $700,000 distribution. Assuming this relationship, corporation *x* has a break-even point of approximately 85 per cent while corporation *y* need utilize only 65 per cent of its facilities to break even. If the operating level could be advanced without any significant shift in fixed costs, it is obvious that *x* would have a distinct advantage. Allocation of its fixed charges over proportionately more units, together with a much lower variable-cost rate per unit, would tend to provide a much wider profit spread. Conversely, if capacity utilization declined below the rated 100 per cent level, then corporation *x*'s profits would diminish rapidly and become losses be-

low the 85 per cent level. On the other hand, y would expand profits at a slower rate, assuming production could be moved beyond the current 100 per cent rated level. Similarly, the no-profit zone begins and continues downward from the 65 per cent level.

While the previous example stresses the hazard involved in attempting to equate operating situations and to derive an over-all desirable break-even point, there are some generalizations applicable to this subject. In cases where an extremely high investment is required relative to net income, a low break-even point becomes more advantageous. If, together with this characteristic, there is a high risk factor and high variable costs, then a very low break-even point becomes mandatory. Where the reverse situation exists, namely, low investment coupled with low risk and low variable costs, a high break-even point can be associated with high profits.

This technique has tremendous significance for policy-making purposes. The administrator, by a relatively simple scanning of a factual and graphic presentation, can gain a more intimate acquaintance with circumstances vital to the decision he must render. Not only top-level administrators but even branch or plant managers, department heads, and staff functionaries can use this device to distinct advantage. Common sense should indicate that this technique is not an infallible tool. Its usefulness is abridged or enhanced by the technical competency, prudence, and executive ability of the user.

TECHNIQUE 3. Predetermined, or Standard, Costs

The concept of standardization as a prerequisite for modern management was analyzed in Chapter 4. References have been made and will be made in various chapters stressing the significance of standardization for concepts and techniques pertinent to management. In particular, the subject applies to techniques such as work measurement, quality control, job description, job evaluation, production control, and equipment utilization. In the area of cost control, the application of standards to measures of performance is equally important. As early as 1911 Harrington Emerson developed the basic principles of the standard-cost concept. In substance these principles stressed that:

1. The approximate cost of production of a good or service should be known even prior to the performance of the requisite activities.
2. Variance between the standard and actual costs is assumed as inevitable.
3. In addition to being observed, variances should be studied to determine their causes.

4. The exception principle should be followed in the analysis of cost variances.

5. Use of standards for labor, materials, and overhead expenditures facilitates control over industrial performance.

Predetermined costs are usually contrasted with actual costs. It is evident that complete reliance upon actual costs would seriously hinder effective planning since all plans, by definition, are geared to the future. If decisions had to wait until pertinent actual costs were recorded, all planning would assume either short-run proportions or a stereotyped form. Thus it is imperative for many types of activity to use cost estimates based on accepted standards and correlated to some measure of time or use. Subsequent adjustments can readily be made in the light of actual experience. This adjustment should account for variances in all the major cost components. If these variances are kept within acceptable tolerances, then, for all practical purposes, the predetermined costs are comparable to anticipated actual costs. By this means planning and control are significantly facilitated.

Standards in costing can be applied to every component of an organization and to every factor and subfactor of production. It is needless to say that within a single organization there can be different standard costs for the same item when geographical, historical, or other factors make such heterogeneity mandatory. While such differences are not necessarily desirable, they do reflect a common-sense approach in the adjustment to circumstance.

Fundamentally, predetermined costs are set by either current standards or basic standards. Current standards presumably set a norm which should be readily approximated under the prescribed conditions. Costs determined by current standards are real in so far as they are carried on the corporate books and serve as a basis for records and reports. Periodic adjustments of such standards are essential if the predetermined costs are to be representative costs. When variance does occur, adjustments should be made at specified intervals.

Basic standards are, as indicated in the title, more universal and longer-enduring. This type of standard necessitates a conversion of either the current standards or the actual costs into percentages of the basic standard. These basic standards are invariably conditioned by technological factors and tend to remain constant as long as a particular process continues substantially unchanged.

Standards, whether current or basic, are effective as long as the differential between the standard and the actual performance is insignificant. Because of the numerous variables affecting industrial activ-

ity, it is impossible to make an exhaustive compilation of all causes of cost variance. Among the more important are:

1. Unforeseen product-price changes
2. Increases and decreases in costs of productive factors
3. Changes in selling techniques
4. Shifts in manufacturing processes
5. Modifications in capacity utilization
6. Variations in productivity
7. Scheduling adjustments

These variances are invariably in reference to price or quantity. Conversion from one unit to the other is a matter of simple arithmetic when price per unit is known. Variance can also be viewed as controllable or uncontrollable. This distinction is generally made after variances have been properly analyzed. Cognizance of the cause and the extent to which it can be controlled is of great importance to the decision maker.

The following is an abridged version of how the standard-cost technique can be applied to a typical industrial-management situation. A manufacturer of low-priced men's dress shirts calculates unit costs by the predetermined-cost method. For the month of January, sales forecasts and production planning called for an output of 90 lots of shirt style *A*, and 70 lots of shirt style *B*. One lot consists of 12 dozen, or 144 units. Labor costs average $1.20 per hour in the making of both types of shirts. Approximately 0.6 man-hour is needed to make a style *A* shirt. The style *B* product requires 0.4 man-hour. Material costs average $0.50 per square yard for shirt style *A*, and $0.40 per square yard for shirt style *B*. Two square yards of material are consumed in fabricating the former, while the latter requires, on the average, 2.2 square yards of material. The standard rate for indirect variable costs is set at $0.30 per man-hour, and the standard rate for the indirect fixed costs is $0.40 per man-hour.

The standard-cost rate per lot of 144 units is computed as shown in Exhibit 15-9.

It should be noted that the direct costs are first computed on a quantity basis, in terms of man-hours for labor and square yards for materials. Another point to keep in mind is the specific method used for allocating indirect costs by means of a man-hour base. There are other equally acceptable techniques which can be used for this allocation. The cost per unit is derived by dividing total standard costs per lot by the number of units in the lot. This standard cost per shirt, assuming all the pertinent data are reliable, provides a yardstick for sales and production planning. It also serves as a criterion which, if

Exhibit 15-9

Cost per lot	Shirt style	
	A	B
Direct man-hours	86.4	57.6
Direct materials, square yards	288.0	316.8
Direct labor	$103.68	$ 69.12
Direct materials	144.00	126.72
Indirect costs:		
Variable	25.92	17.28
Fixed	34.56	23.04
Total, per lot	$308.16	$236.16
Total, per unit	$ 2.14	$ 1.64

not met, warns the policy makers of serious imperfections in their planning premises.

In this case, using the standard-cost rate per unit and multiplying by the quantity the production planners propose for manufacture during this particular period, a budget can be set up showing total anticipated costs. Exhibit 15-10 depicts such a budget.

Exhibit 15-10. Standard Costs for Month of January on the Basis of 90 Lots of Shirt A and 70 Lots of Shirt B

	Shirt style	
	A	B
Direct man-hours	7,776	4,032
Direct materials, square yards	25,920	22,176
Direct labor	$ 9,331.20	$ 4,838.40
Direct materials	12,960.00	8,870.40
Indirect costs:		
Variable	2,332.80	1,209.60
Fixed	3,110.40	1,612.80
Total standard cost	$27,734.40	$16,531.20

This information aids management in obtaining the requisite manpower, materials, productive facilities, and finances. For example, provision must be made for at least $44,265.60 for payment of costs to be incurred. Of course, some of the indirect costs might be deferred,

but eventually operations at the scheduled level will result in expenditures that must be properly discharged.

At the end of the period or soon thereafter actual costs should be available. Management can then compare the standard costs with those actually incurred. In this instance, actual production amounted to only 85 lots of shirt style *A*, and 68 lots of shirt style *B*. From this rather general information, it can readily be deduced that neither norm of 90 and 70 lots, respectively, which the production planners had originally set, was reached. Consequently, comparisons between the actual costs and the total of standard costs, as shown in Exhibit 15-10, might be subject to misinterpretation. An expedient measure would be to project the standard-cost totals into terms of the 85- and 68-lot outputs of shirts *A* and *B*, respectively.

Exhibit 15-11. Standard Costs for an Output of 85 Lots of Shirt A and 68 Lots of Shirt B

	Shirt style	
	A	B
Direct man-hours	7,344	3,916.8
Direct materials, square yards	24,480	21,542.4
Direct labor	$ 8,812.80	$ 4,700.16
Direct materials	12,240.00	8,616.96
Indirect costs:		
Variable	2,203.20	1,175.04
Fixed	2,937.60	1,566.72
Total standard cost	$26,193.60	$16,058.88

On this budget, financial requirements should amount to about $2,000 less than the original budget. If considerable portions of the concern's funds are borrowed, this type of miscalculation can be very costly. Even where the organization is amply financed, improper allocation of funds is invariably an index of managerial inefficiency. At this point the actual cost figures should be compared with the preceding tabulation of standard costs to note discrepancies.

Simple inspection should be sufficient to convince management that the anticipated costs and the actual costs for shirt *A* are almost identical. Lower labor and indirect costs were partially offset by somewhat higher materials cost. The variance of minus $50, in a total expenditure of more than $26,000, is only a fraction of 1 per cent deviation.

Direct-labor variance for shirt *A* is only about 1 per cent below the estimate. Direct materials costs exceed the budgeted sum by about three-fourths of 1 per cent. In this instance there is a high measure of conformity between the standard and the actual costs.

The figures relevant to production of shirt *B* present quite a different picture. Total-cost variance is 11.4 per cent above the sum budgeted on the basis of standard costs. The 19 cents higher unit cost will probably wipe out the margin of profit and presumably will lead to an operating loss on this product. Seeking the causes for this apparent blunder in planning, management could easily note that the budgeted and actual material costs are practically identical. The standard rate of 2.2 square yards of fabric per shirt is a remarkably good allowance.

Exhibit 15-12. Actual Costs Incurred in the Production of 85 Lots of Shirt A and 68 Lots of Shirt B

	Shirt style	
	A	B
Direct man-hours	7,270	4,888
Direct materials	24,660	21,501
Direct labor	$ 8,724.00	$ 5,865.60
Direct materials	12,330.00	8,600.40
Indirect costs:		
Variable	2,181.00	1,466.40
Fixed	2,908.00	1,955.20
Total actual costs	$26,143.00	$17,887.60
Unit actual costs	$ 2.13	$ 1.83

However, in the direct-labor category, there is a significant disparity between the standard rate and actual expenditures. The $1,165 differential is an increase of nearly 25 per cent over the anticipated costs. Since both categories of indirect cost are linked, in this instance, to direct-labor costs, the miscalculation becomes even more exaggerated. The very obvious and immediate reaction of the production planners should be a thorough investigation to discover the causes for this discouragingly high variance. There is, for example, a possibility that the current standard direct-labor rate of 0.4 man-hour for shirt *B* might be obsolete. If the standard had been set at 0.5 man-hour per unit, there would be practically no difference between standard and actual costs. On the other hand, the variance might have been caused by one

or more inefficient practices prevalent in the labor force. Until the cause or causes have been isolated and corrective measures instituted, it is useless to attempt anticipating costs for production of shirt style *B*.

In summary, it should be noted that costs set by standard rates are not always identical with what are familiarly known as cost estimates. Although both methods are empiric techniques based upon the collection of facts pertinent to related past experience, estimates in the strict sense are largely opinions. At best a cost estimate might be termed the product of a systematic approach to a production problem. On the other hand, a cost standard is the result of application of scientific methodology to the relevant data. Admittedly, the line of demarcation between the systematic and the scientific in the sphere of cost analysis can at times become rather indeterminate. However, there need be no concern over this seeming duality. In a case where the systematic estimate cannot be differentiated from the scientific standard, in all probability they are both equally good and will yield equally satisfactory results.

ILLUSTRATION 1. Common Sense and Cost Analysis

The scientific technique by definition demands that masses of information be collected and analyzed before conclusions are set forth. This information must be detailed, precise, and relevant; otherwise the validity of the conclusions can be seriously questioned. On the other hand, an overzealous adherence to minutiae can be costly and confusing. It should be apparent that in the area of cost control considerable common sense is needed to find the balance between an adequacy of cost records and a plethora of incidental and irrelevant figures.

Apropos of this problem, the Controllers Institute of America has recommended the adaptation of the principles of motion and time economy to cost control and accounting techniques. In particular, the Institute endorsed recommendations for a more universal acceptance of the "whole-dollar" accounting concept. This concept, also known as "centsless accounting," "pennyless accounting," "penny elimination," and "controlled tolerance accounting," proposes that as soon as is feasible in the recording of data, the decimal point and fractions of a dollar be dropped from the accounting records. Emphasis is placed on the "as soon as is feasible" aspect since, as is pointed out by the Controllership Foundation, the research section of the Controllers Institute, most companies practicing whole-dollar accounting begin rounding numbers consisting of five digits plus decimal point.

The Controllership Foundation lists the following advantages obtained from whole-dollar accounting:[2]

1. Reduction in physical work—in the motion and time sense—required for:
   a. Recording and posting to accounts.
   b. Transcribing, computing and totaling, analyzing and tabulating accounting data.
   c. Balancing and closing the books.
2. Increased productivity of accounting and related operations reflected in one or more of the following ways:
   a. Increased output per employee-time unit.
   b. Improved quality of work.
   c. Actual reduction in clerical costs. In other words, increased productivity is manifested in a reduction in the staff needed to do the same job, by an increased volume of work done by the same number of people; also in the form of higher quality, more accurate work.
3. Reduction in incidence of error, and when an error is made, greater facility in locating, identifying, and correcting it. All companies having had "normal-run" experience with whole-dollar accounting report this as a significant gain.
4. Statement and report preparation time is reduced as a result of the compounding effect of the preceding factors. This means that management gets statements and reports earlier than was possible before.
5. Improved, more effective statement reports
   a. Simplification of data through eliminating the penny detail makes for less crowded, less cluttered, more readable reports and statements.
   b. Dropping insignificant digits in statements and reports (which invariably follows from whole-dollar accounting) helps management identify more readily the significant items and relationships among the data contained in the reports.
6. Effective capacity of existing report and record forms is increased by eliminating two penny digits in each column or series (or two digits plus decimal point). This makes available space for inclusion of additional significant series without increasing the size or complexity of the report or record form. Conversely, should additional series be unnecessary, reports and records forms can be simplified in design and reduced in size.

[2] F. A. May and H. F. Klingman, *Whole Dollar Accounting*, Controllership Foundation, Inc., New York, pp. 14–15.

7. Morale of accounting, statistical, and other personnel affected is materially improved.
8. Finally, all concerned cite as a distinct advantage the fact that the whole-dollar accounting concept and technique are simple. Compared with many other system and procedure changes this makes it relatively easy to install successfully.

There seems to be no doubt that real benefits follow from the application of this office-work-simplification technique. As previously stated, most proponents of whole-dollar accounting recommend its use with numbers containing five or more digits. Eliminating the last two digits, together with the decimal, from the figure 381.66, for example, cuts the clerical work in recording, etc., by about 50 per cent. This percentage declines, obviously, as larger numbers are handled. The percentage gain in efficiency should also reflect the other advantages, such as the decreased probability of error. Even a conservative estimate of 10 per cent gain in record-keeping effectiveness would seem to justify installation of this method.

Striving to present an impartial analysis of the whole-dollar approach, the Controllership Foundation also lists a series of disadvantages associated with the technique:[3]

1. Whole-dollar accounting connotes abandonment of the double-entry principle in accounting.
2. It will result in loss of control and will open wide the door for encouragement of "plugging" by unscrupulous bookkeepers and accountants.
3. Whole-dollar accounting will have a bad effect on employees' attitude in the sense that it will:
   a. Encourage carelessness and inaccuracy in accounting operations.
   b. Cause more, rather than fewer, errors to be made in accounting operations because of the necessity for "rounding" to a full dollar.
4. Rounding to the nearest dollar will result in serious cumulative variances.
5. Whole-dollar accounting will cause more trouble and work than it will save.
6. Whole-dollar accounting may cause difficulties with governmental agencies, notably taxing authorities and regulatory bodies.
7. Mathematical difficulties and limitations:
   a. The percentage of variance (or error) in the difference between two numbers may be considerable, as a result of the rounding technique, whereas the percentage variance, or "error," induced

[3] *Ibid.*

by rounding each of the two numbers being differenced would be insignificant.

b. The absolute distortion or variance resulting from extending unit prices or unit costs multiplied by large quantities will likely prove to be intolerably large. Therefore it is best that unit prices and unit rates be carried to just as much refinement, or degree of accuracy, as ever.

The whole-dollar concept was first introduced by a major corporation in 1927 in the Bethlehem Steel Corporation at the suggestion of its comptroller, F. A. Shick. Bethlehem Steel has been a consistent proponent of the technique ever since. In answer to the limitations just listed, Bethlehem Steel's record for 1956 shows that on total billings of $2,341 million, the net variance was $5,098, or only $2.18 per million dollars of billings. Other comparable examples are furnished by Colgate-Palmolive, which in a three-year period had a cumulative net variance of $980 on sales of approximately $900 million. Time, Inc., had a net variance of about $500 after a six-year period during which sales totaled nearly one billion dollars.

These illustrations seem to substantiate the claim that whole-dollar accounting has considerably more merits than faults. This analysis of the technique is not intended to be a description of or justification for a particular accounting method. Far more important is the basic approach by which common sense is used to modify the scientific method. Detail can be vital to decision making. Then too, the administrator can become so bogged down in trivia that his effectiveness in upper-level policy making and implementation can be seriously impaired. It is very important that a judicious line of demarcation be drawn between the useful and the incidental. The proponents of the whole-dollar accounting method believe they are supporting a proposal which will help management more effectively control the organization on the basis of ample facts but without a superfluity of such facts.

QUESTIONS

1. In what instances might it be difficult to justify the use of whole-dollar accounting?
2. Is this a step backward from the precision of scientific methodology?
3. Does the whole-dollar approach have equal significance where record keeping and computations are done by mechanical and electronic devices?

ILLUSTRATION 2. Inventory Budgeting

The managers of the concern making the air conditioners, mentioned earlier in the chapter, are considering the feasibility of two

extremes of production scheduling. Since inventory costs, as measured by the inventory budget, are rather excessive, it has been proposed that a hand-to-mouth inventory policy be instituted. This would mean only a nominal inventory charge. On the other hand, proponents of production stabilization have suggested that the total annual requirements of 13,600 units be produced in 12 equal monthly production orders of approximately 1,150 units per month. Both these alternatives were based upon the following assumptions:

Average unit production costs	$ 115
Average unit selling price	150
Unit carrying costs per month	3
Setup costs per 100 units of output	1,400
Breakdown costs per 100 units of output	800
Annual cost of increasing capacity to meet hand-to-mouth requirements	65,000

The setup and breakdown costs include a variety of charges arising out of precipitous expansion or contraction of product flow. Among these charges are labor costs resulting from recruitment, training, overtime, fatigue, severance, and other related items. Reactivating and deactivating equipment are also costly procedures. Sudden shifts in supervisory personnel likewise tend to be uneconomic.

If the hand-to-mouth technique were to be followed, then the current maximum capacity requirement of 2,100 units would be increased to the 3,500-unit level. This additional capacity would not be utilized for a significant portion of the year. Thus the idle capacity would boost overhead charges. This excess cost has been estimated at $65,000 on an annual basis.

QUESTIONS

1. Compute the inventory charges plus setup and breakdown costs for (*a*) the current method; (*b*) the hand-to-mouth proposition; (*c*) the stabilized-production alternative.
2. What nonmonetary considerations affect inventory budgeting and inventory policy?
3. Under what circumstances is it advisable to meet the peak-demand periods by use of widely fluctuating inventories?

ILLUSTRATION 3. A Break-even-point Case

A seashore resort hotel, catering both to convention groups and to summer vacationers, has a permanent staff of 5 administrative officials and 12 employees. The annual salaries and wages are approximately $48,000 and $96,000 for the respective staff components. The hotel has maximum accommodations for 400 guests. Average fee per guest-day is $8.25. When more than 200 guests are accommodated, additional help,

at the rate of 1 staff member per 20 guests, must be secured. This type of help costs about $400 per person per month. Other variable costs are estimated as averaging $3 per guest-day. Taxes, insurance, and related costs come to $8,000 per month. Capital costs, including depreciation and interest, add another $16,000 per month to operating expenses.

The seasonality factor in the hotel industry has prompted the decision makers in this instance to consider reducing the regular staff of employees from 12 to 4. While this would reduce to about one-third the annual wages for this type of help, it would also reduce proportionately the 200 guests-per-day base which presently can be serviced by the permanent staff. With the proposed reduced staff, as additional guests, above the 100 guests-per-day figure, were registered, proportionately more staff at the 20:1 ratio would be needed.

QUESTIONS

1. Convert these data into a graphic break-even presentation.
2. What is the profit-loss situation at the 200 guest-day level?
3. Is there any significant change when capacity utilization reaches the 75 and 100 per cent levels?
4. Compute the break-even point.
5. Show graphically the effect of the proposed staff modifications.
6. Would you recommend the change?

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CHAPTER 16

Quality Control

DEFINITION AND DESCRIPTION

Quality control is a technique whereby judgment is rendered as to a specific item's acceptability or nonacceptability for utilitarian purposes. In every instance acceptance or rejection is made on the basis of standards either expressed or implied. Rigidity in adherence to these standards varies considerably, depending upon the specific technique employed, the need for precision, cost factors, and company policy as to the importance of quality.

Fundamentally, every quality control technique consists of:

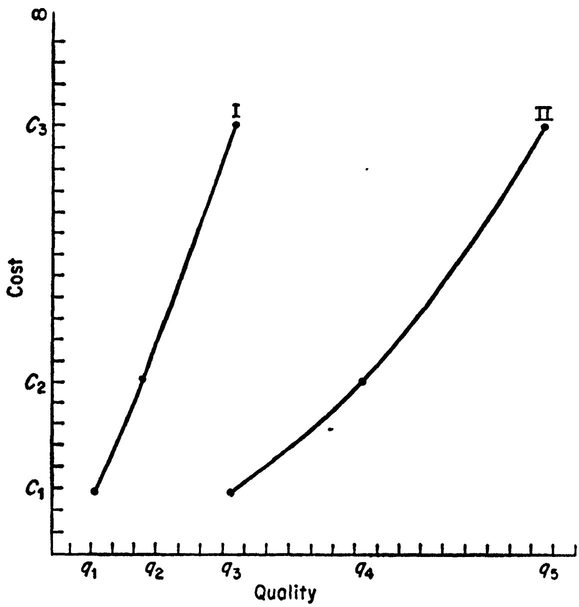
1. The establishment of standards
2. The prescription of means by which these standards can be attained
3. Observation of the product to note the existence or nonexistence of the desired traits
4. A judgment as to the adequacy of the manifested traits in terms of the standard
5. Application of corrective measures when deemed necessary

Any consideration of quality control must, of necessity, begin with an analysis of standards and specifications. A review of Chapter 4 would assist immeasurably in a better comprehension of the historical basis, terminology, and objectives relative to both standards and the control of quality. This is important in so far as all quality and control of quality are relative. There is no such thing as absolute and immutable

perfection in the realm of economic goods. Consequently, the inevitable changes in products resulting from modifications in processes, materials, or consumer preferences necessitate comparable adaptations in the prescribed standards and specifications.

The fundamental policy-making function in the sphere of quality control is expressed graphically in Exhibit 16-1. It is the policy maker's

Exhibit 16-1. Cost-Quality-Technology Relationships



function to determine the extent to which inspection and the other quality control techniques should be utilized, considering both the relative degree of quality desired and the accompanying costs. In this portrayal cost increments are measured on the vertical scale while improvement in quality is indicated on the horizontal scale. Assuming a given technological level, the interrelationship of cost and quality can readily be depicted by curves such as those labeled I and II. In every instance these curves tend to become perpendicular to the base, thus indicating a situation where, after a point, even an infinitesimal improvement in quality can be effected only by prohibitive increases in cost. This "diminishing-returns" characteristic is expressed by the cost-curve scaling extending to infinity (∞).

As changes in technology occur, the cost-quality curves generally move farther to the right, indicating that because of technological

progress higher quality is obtained with no proportionate increase in cost. This is particularly true in the lower reaches of the curve. Then too, a quality product previously unattainable becomes available—at a price—as technology progresses. The policy maker must, obviously, decide if and when the technological changes requisite to product improvement are worthy of adoption.

In the chart, points C_1, C_2, and C_3 represent three different cost combinations in the proportions 3:8:20. Under conditions imposed by technological level I, C_1, C_2, and C_3 yield qualities of q_1, q_2, and q_3, respectively. In this instance these qualities have a 2:4:8 relationship.

Shifting to technological level II, the costs C_1, C_2, and C_3 produce qualities of q_3, q_4, and q_5, which have an 8:14:22 relationship. Evidently much more quality is obtained with no proportionate expenditure of money. Despite the absolute gains, however, it should be observed that invariably, after a given point, qualitative improvements tend to cost more per unit. Thus in curve I, the C_1q_1 item is obtained at an average of 1½ cost units. Moving to the C_2q_2 level means an added cost of 5 units, which give only 2 extra units of quality. The marginal unit cost for this extra quality has thus increased from 1½ to 2½ units. At C_3q_3 the marginal-cost increment is 3 units per unit of quality. Average costs likewise increase, although in a less precipitous fashion, in the ratio 1½:2:2½.

Similarly, in curve II the marginal, or extra, quality is obtained only by progressively larger cost expenditures, from 3/8 to 5/6 and then to 1½ cost units per unit of quality. Again average costs also increase, but in a more modified manner, from 3/8 to 4/7, and then to 10/11 cost units per quality unit.

From the foregoing it can be assumed that invariably qualitative improvements tend to become more and more expensive as the upper levels of quality are sought. It is the function of the policy maker to find the optimum in terms of prevailing costs, available technological improvements, and present and potential effective demand for the product. Proper analysis in this regard, together with successful implementation, is the best assurance for competitive excellence.

While determination of the prevailing cost-quality level is a major function of the policy maker, the more evident quality control functions involve the determination of methods for detecting and eliminating defective items so that the consumer will be assured of a quality product. Even more important, the upper-level decision makers must devise methods of process control yielding a high degree of assurance that the number of defectives will be rigidly controlled within predictable ranges. This ability to predict and to control the

process serves to distinguish quality control from the more mundane inspection function. Inspection pertains to the detection and elimination of imperfect items *after* they have been manufactured. Quality control, in addition to the inspection function, aims at foreseeing and avoiding the manufacture of imperfect items by the application of control techniques.

It has already been emphasized that the prime function of quality control pertains to the determination of cost-quality levels. Having decided upon a given level, techniques must be found to predict the probable quality which will result under given operating conditions. Fairly accurate prediction will then make possible better control of the manufacturing process. As with all scientific-management techniques an empirical analysis is absolutely essential. This means that inspection is fundamental to all quality control techniques. In this context, inspection is simply the checking of products to determine whether or not they conform to specifications. The completeness of the inspection process is the basis for differentiating the two major types of quality control methods: 100 per cent inspection and sample inspection. In turn, these methods can employ visual-manual, mechanical, or automatic processes.

100 Per Cent Inspection. As implied in the title, 100 per cent inspection consists in the checking of every item in the group to determine the incidence of a specific characteristic. Presumably such thoroughness in checking should yield a high degree of confidence in the product's acceptability. However, human frailty frequently injects errors of judgment which lower effectiveness. Inspectors, likewise, vary in competency; hence disparity as to conclusions frequently follows. There are numerous instances where the same batch of product is very differently evaluated by several inspectors, particularly if variable qualitative features are being analyzed. The time consumption, high labor cost, and even the differences of inspectors' opinions frequently make 100 per cent inspection onerous and undesirable.

Sampling. Fundamentally all sampling inspection can be viewed as serving one or another of the following purposes:

1. Lot-by-lot sampling, where a sample is drawn and the lot is accepted or rejected on the basis of the quality observed in that sample. This is the general procedure in acceptance sampling, which will be described as one of the important techniques currently in use.

2. Continuous sampling, where the results of inspection provide the basis for deciding the extent of the inspection to be made of subsequent items.

3. Inspection for variables, in which a precise measurement is made

of the specific characteristic to determine whether or not it meets the requirements.

4. Inspection for attributes, which pertains to the analysis of the sample to determine whether or not the characteristic is present. In application this generally means that a decision must be made as to whether or not the item is defective or acceptable.

All sampling techniques rest upon the principles of logic as set forth in corollary 1, Chapter 7. Both the deductive- and inductive-reasoning processes are applicable. The inspector uses the deductive method when, upon examining an item, he notes the presence or absence of a characteristic and relates this observation to certain basic assumptions or general principles. Thus an inspector in a pretzel factory works on the basic assumption that every pretzel must contain certain prescribed twists. Too little or too much twist indicates nonconformity and non-acceptance. The same inspector uses the inductive method when, after noting a sequence of 999 properly twisted pretzels, he assumes that the final item in a batch of 1,000 will also be a relatively perfect pretzel.

The logic that inferences can be made concerning a large group on the basis of characteristics observed within a sample representation from that group is closely associated with the laws of probability. Reference has been made previously, and specifically in the beginning of Chapter 8, to the meaning, uses, and limitations of probability analysis. In Chapter 8 a simple example was set forth describing the procedure by which the probabilities, derived from an expansion of the binomial, can be applied to an industrial situation. The probability that a particular event will happen (p^1) or that it will not happen (q^1) depends upon an empiric analysis, that is, a study of average past performance, conditioned by foreseeable modifications in parameters. The example in Chapter 8 showed that in a process which in the recent past has had an experience ratio of 94 per cent acceptable, if samples of five items each were tested, the following distribution shown in Exhibit 16-2 would hypothetically result.

Exhibit 16-2

Number of defects	Relative frequency of occurrence
0	0.733904
1	0.234224
2	0.029901
3	0.001909
4	0.000061
5	0.000001

The formulas and calculations incident to deriving the relative frequency of occurrence in this example of subgroups of five, when the process has been averaging 94 per cent acceptable product, have been intentionally omitted. It is deemed expedient, in a text of this type, to avoid the complex statistical analysis which is essential to application of quality control techniques. Far more important to the student of management is the comprehension of the importance and place of the quality control function for effective industrial organization. Nevertheless, an individual striving for recognition within the quality control department must, obviously, develop a competency in statistics. Determination of sample size, actual selection of the sample, computation of probabilities, analysis of variance, measurement of correlations, and similar phases of quality control are absolutely impossible without a thorough grooming in statistical technique. However, despite this stress on statistics, it should be emphasized that it is a commonplace occurrence, in and out of industry, to draw conclusions as to group characteristics on the basis of traits manifested within a subgroup with little or no use of mathematical calculations. This is the essence of sampling. Statistical sampling is simply a projection of scientific methodology into this important sphere of decision making and control relative to a product's quality.

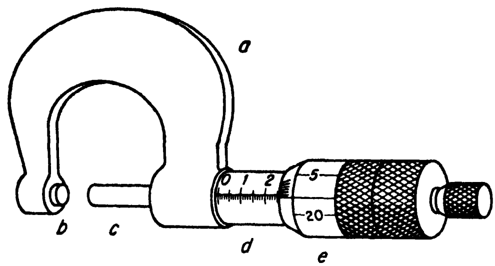
Visual-Manual Inspection. This is the oldest and still the most commonly used quality control device. It consists in the observation by the inspector, through use of his senses, of specific items to determine whether or not they have certain desired characteristics. If a wanted characteristic is present, its degree, magnitude, or intensity is also frequently estimated. Thus, despite its simplicity, visual-manual inspection is, nevertheless, a decision-making process.

Visual-manual inspection has been, up to recently, a relatively inexpensive technique. It continues to be a particularly usable technique where a simple decision is to be rendered as to the existence or nonexistence of a certain attribute. Considering its extreme reliance upon human factors, it is obvious that errors of judgment and differences of opinion would be inherent in this type of inspection. This would especially be the case where the product being scrutinized entails very fine measurements or subtle nuances in color, shape, weight, etc. Recognizing the steadily increasing demands for better quality based on finer and more rigid specifications, it can readily be inferred that visual-manual inspection has a limited application. In addition, the significant increase in wage levels has, in many cases, boosted this technique's labor costs to prohibitive proportions. As a consequence, quality control managers have had to take recourse, in more and more

instances, to mechanical or automatic devices and especially to sampling techniques.

Mechanical Inspection. The introduction of calipers, micrometers, and limit gauges of all sorts marked a transition from inspection relying entirely upon human senses and judgment to a quasi-mechanical process. A caliper, as defined in Webster's New Collegiate Dictionary, is simply an instrument with two legs, usually curved, fastened together with a rivet or screw or with a spring and pivot. An outside caliper is used in measuring external thicknesses, diameters, or distances, while an inside caliper measures comparable internal dimensions. A micrometer caliper, as depicted in Exhibit 16-3, consists of a

Exhibit 16-3. A Micrometer



frame (*a*), anvil (*b*), movable spindle (*c*), sleeve (*d*), and thimble (*e*). Turning the thimble (*e*) through each one of the 25 divisions on the beveled scale moves the spindle (*c*) 0.001 inch toward or away from the anvil (*b*). A vernier attachment can be used, adapting the caliper to very fine measurements of 0.0001 inch.

All types of calipers, including the micrometer, have the advantage of flexibility and the parallel limitation of being subject to human frailty. An incompetent inspector can easily reduce the effectiveness of these instruments. In addition, the repetitiveness of the operation and the time-consuming aspects necessarily result in high labor costs. As a consequence, production specialists developed a variety of gauges which in effect are calipers "frozen" at one specific dimension. These fixed gauges include the well-known ring, plug, and go–no-go gauges. With these very simple devices a rapid matching or fitting indicates whether an item is acceptable or whether it is above or below the required limits. Reliance upon the inspector's judgment is drastically reduced. There is no need to set and reset the gauge or to read the dimensions.

Although the flexibility feature is sacrificed in fixed gauges, there is

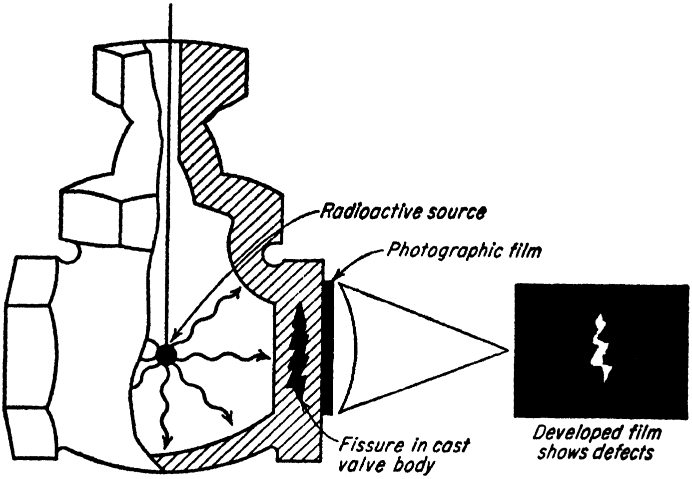
a tremendous gain in the facility with which they can be used and in the high degree of confidence that accompanies their use. Once the dimensions have been set there is need for only a periodic check by means of a master gauge to determine if time or use has effected any unwarranted changes.

The flexibility factor, while being sacrificed in the fixed gauge, is used to great advantage in a wide variety of indicating gauges such as micrometers, dial indicators, air-indicating gauges, and optical comparators. In addition to corroborating the existence or nonexistence of a specific characteristic, this type of gauge also measures variations in the quantity and quality of this characteristic in the item being inspected.

The decision as to what type of gauge, fixed or indicating, should be used is generally contingent upon the manufacturing process. In general, although quality control techniques have tended to become more and more mechanized, there seems to have been a lag in mechanizing in this sphere as contrasted with the pace of mechanization in actual production operations. This phenomenon is shown graphically in Exhibit 3-3. In this example of the degree of mechanization at successive work stations in the processing of engine blocks at the Ford Motor Company's highly automated Cleveland plant No. 2, 44 separate operations are designated. Of these, 9 are specifically classed as inspection operations. Only 11 of the 44 operations are placed in the lower three categories of mechanization. These 11 instances include all 9 inspection operations. This example typifies the relatively slow progress industry has made in more completely mechanizing the inspection and quality control functions.

Automatic Inspection. Despite the relative lag in the widespread adoption and perfection of quality control techniques some significant strides have been made in certain areas in the more complete mechanization of the inspection function. There is a steadily increasing introduction into industrial use of photoelectric cells, solenoids, beta rays, and a great many other recently discovered scientific devices. Atomic research in particular has contributed much in the application of radiography to industrial quality control purposes. Within the past few years the Federal government has made available for industrial and research purposes large quantities of gamma-ray-emitting isotopes such as cobalt 60 and iridium 192. The use of radioisotopes permits rapid and relatively low cost inspection of internal dimensions and other characteristics in items such as valves, motors, tanks, etc. Such inspection previously could only be made prior to assembly or not at all. Exhibit 16-4 shows how radioactive cobalt, Co 60, is used for

Exhibit 16-4. Radioactive Cobalt, Co 60, for Radiography Testing

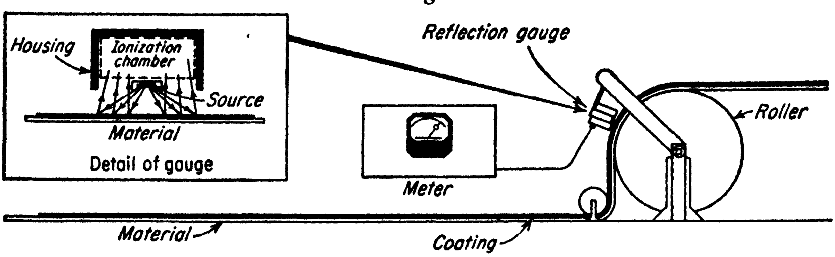


ADVANTAGES: (1) Versatile and reliable inspection; (2) inspection made without dismantling; (3) sources of desired shape and size; (4) very-high-activity sources available at low cost.

SOURCE: *Proceedings Ohio Conference on Peacetime Uses of Nuclear Energy and Radiation Safety, August 29, 1956, Columbus, Ohio,* Industrial Commission of Ohio, Columbus, Ohio.

radiography testing of a valve. There is no physical contact between the measuring device and the material. The technique is convenient and gives a degree of accuracy previously unattainable. Exhibit 16-5 depicts the use of a radioactive substance in the continuous gauging

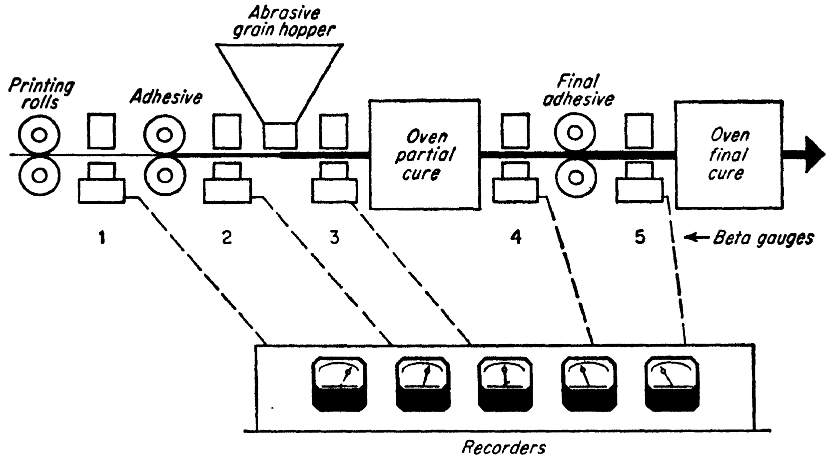
Exhibit 16-5. Radioactive Source for Reflection (Backscattering) Thickness Gauge.



ADVANTAGES: (1) Can measure thickness of coating and/or material; (2) measurement made from one accessible side; (3) can measure a variety of materials with one calibration.

SOURCE: *Proceedings Ohio Conference on Peacetime Uses of Nuclear Energy and Radiation Safety, August 29, 1956, Columbus, Ohio,* Industrial Commission of Ohio, Columbus, Ohio.

Exhibit 16-6. Use of Multiple Beta Gauges

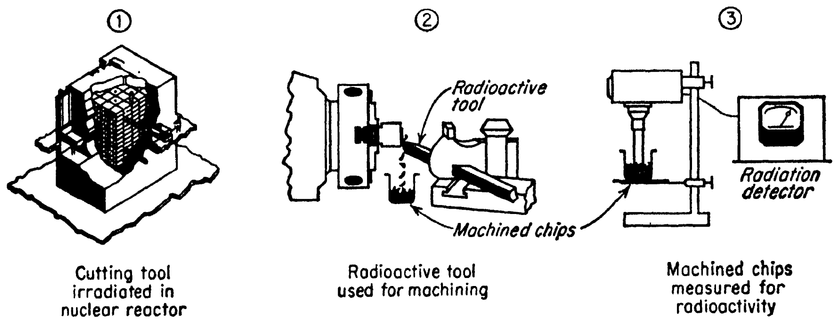


SOURCE: *Proceedings Ohio Conference on Peacetime Uses of Nuclear Energy and Radiation Safety, August 29, 1956, Columbus, Ohio,* Industrial Commission of Ohio, Columbus, Ohio.

of thickness in a product. Exhibit 16-6 shows how a series of beta gauges can be adapted to an automated operation with a separate recorder for each operation.

Considerable strides have been made in the use of radioisotopes for quite a different aspect of quality control in wear and corrosion

Exhibit 16-7. Measuring Cutting-tool Wear and Life by Radioactivity Tests



ADVANTAGES: (1) More reproducible and sensitive than other tests; (2) faster and more efficient; (3) yields knowledge of wear process.

SOURCE: *Proceedings Ohio Conference on Peacetime Uses of Nuclear Energy and Radiation Safety, August 29, 1956, Columbus, Ohio,* Industrial Commission of Ohio, Columbus, Ohio.

studies. Tracer radioisotopes are introduced into a machine part, cutting tool, or engine component. Radioactivity tests are made, for example, of the machined chips. The amount of removal of the radioactive substance, as shown in the machined chips, indicates the rate of removal, and hence the wearing quality of the machine tool. This technique is graphically depicted in Exhibit 16-7.

From this relatively simple presentation it should be evident that the quality control manager and related decision makers must decide as to:

1. The level of quality sought
2. The extent to which imperfect items can be tolerated in a process or batch
3. The probable conformity or nonconformity of a process or batch to predetermined tolerances
4. The inspection medium and method
5. The qualitative adequacy of operations
6. Possible improvements

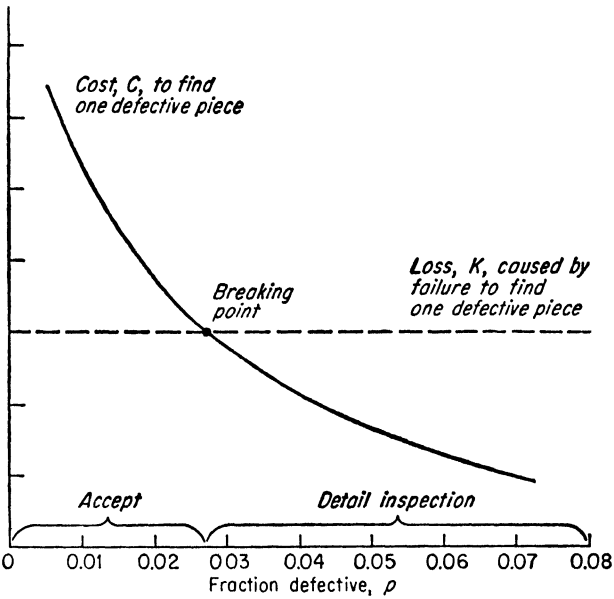
TECHNIQUE 1. Acceptance Sampling

Sampling has been defined as the process of inferring the existence, magnitude, or nonexistence of a characteristic in a group or universe, through observation of a portion of the components of that group or universe. Acceptance sampling, in turn, is a technical process which, using sampling techniques, establishes criteria for determining the extent to which defective items can be tolerated in products which are accepted. This inspection for acceptance on the basis of samples is useful in all stages of manufacturing from raw-material procurement, through processing, and particularly in marketing the product. It has previously been mentioned that absolute perfection in the economic sphere is seldom expected and seldom attainable. The basic question arises, then, as to the degree to which practical considerations dictate that imperfection be tolerated.

The logical procedure by which quality control policy makers set acceptance-rejection levels can be inferred from Exhibit 16-8, in which unit inspection costs (C) are compared with unit costs resulting from failure to detect imperfect items (K). This second type of cost follows from the expenses incurred in scrapping imperfect products, permitting imperfect items to pass into advanced stages of processing prior to detection, and in replacing items rejected by the purchaser. To this category might be added such intangible losses as those resulting from impaired reputation, loss of good will, decreased value of trade-marks,

etc. The *Quality Control Handbook*[1] shows these two sets of costs, C and K, in graphic form with the intersection of these lines, C and K, being termed the *breaking point*. When p, the fraction defective, exceeds the breaking point, it becomes economic to use detail inspection. When p is less than the breaking point, acceptance of the defects becomes warranted.

Exhibit 16-8. The Breaking Point in Sampling Inspection



SOURCE: J. M. Juran (ed.), *Quality Control Handbook*, McGraw-Hill Book Company, Inc., New York, 1951, p. 414.

Fundamentally the same concept is presented in Exhibit 16-9, which compares the relative cost of three alternatives: no inspection, 100 per cent inspection, and sampling inspection. In this instance an operation with an annual output of 50,000 units is being considered. The records presumably indicate that this specific process has in the recent past yielded only about one-half of 1 per cent product so unsatisfactory that management insisted upon scrapping the item because customers demanded refunds or replacements.

Even if every item is individually inspected, it is very unlikely that

[1] J. M. Juran (ed.), *Quality Control Handbook*, McGraw-Hill Book Company, Inc., New York, 1951.

the product will be absolutely perfect. Human frailties, such as fatigue, inadvertence, or incompetency, reduce the effectiveness of 100 per cent inspection, in this case to an estimated 90 per cent. Thus about 10 per cent of the defective product will prove unsatisfactory and be undetected even with individual inspection of each unit.

Exhibit 16-9

	No inspection	100 per cent inspection	Acceptance sampling
Units produced	50,000	50,000	50,000
Units inspected	0	50,000	3,000
Unit inspection cost	0	$0.10	$0.20
Total inspection cost	0	$5,000	$600
Approximate number of unsatisfactory items in the lot	250	250	250
Approximate number of unsatisfactory items passed and later returned for refund	250	25	10
Average cost of one refund or scrapping	$20	$20	$20
Total cost of refunding and scrapping	$5,000	$500	$200
Costs: total inspection cost + total cost of refunding and scrapping	$5,000	$5,500	$800

It should be kept in mind that sampling-technique costs and effectiveness will vary with the rigidity of the particular inspection plan selected. In order to simplify this illustration, the specific average outgoing quality limit (AOQL) sampling-inspection plan for this case hypothetically requires that 6 per cent of the process items be inspected. Unsatisfactory product passed on but subsequently detected is reduced to 4 per cent of total unsatisfactory product.

The cost advantage of sampling inspection in this comparison is obvious since total-quality inspection and guarantee costs amount to only $800 for the sampling method as contrasted with $5,000 for no inspection and $5,500 for 100 per cent inspection. This conclusion is conditioned by the several pertinent variables hypothecated in this illustration. Varying the size of the lot or process, the size of samples, the process average defective, the lot tolerance per cent defective, or the average outgoing quality limit would affect the conclusion. There are numerous industrial situations where no inspection or 100 per cent inspection is preferable. A consistently satisfactory product might warrant a reduction or even an elimination of specific inspection practices.

This is particularly true if unit inspection costs are relatively high while unit production costs and replacement costs are rather low. On the other hand, if there are serious consequences to passing imperfect items, then more rigorous sampling plans, and perhaps even 100 per cent inspection, must be employed.

One of the basic assumptions in acceptance sampling is the premise that there is a high degree of homogeneity in products made on the same machine, by the same process, and within a relatively short span of time. This presumed homogeneity is the basis on which it is concluded that the characteristics observed in the sample are typical of the universe. Consequently, the indiscriminate mixing of lots or process runs prevents the making of legitimate inferences relative to the quality of a process or lot. Thus great care must be exercised to ensure a proper segregation of lots according to process.

Another closely related subject is the method of selecting samples. Randomness is generally assumed to be requisite for proper sampling technique since errors can then be more easily computed and adequate allowances for these errors can be made. In contrast, systematic sampling usually produces unpredictable errors which can be identified, controlled, and compensated only under special circumstances. Published tables of random numbers facilitate the incorporation of randomness into sampling without actually resorting to a physical mixing of the product.

TECHNIQUE 2. Sampling Tables

Published tables are also available to assist the quality control technician in deciding whether or not a specific lot or process contains an excess of imperfect items. The better-known of these tables include:

1. The Dodge-Romig tables for lot tolerance per cent defective.
2. The Dodge-Romig AOQL tables for average outgoing quality limit. Both types of Dodge-Romig tables provide for single sampling and double sampling.
3. The Statistical Research Group, Columbia University, tables for single, double, and sequential sampling.
4. The United States Military Standard tables.

The following description of sampling tables and their function in quality control must of necessity be summary in character. Consequently, only one example each of Dodge-Romig lot-tolerance per cent defective single-sampling and AOQL double-sampling tables will be described. These examples are presented as Exhibits 16-10 and

Exhibit 16-10. Dodge-Romig Single-sampling Lot-tolerance Table

(Lot tolerance per cent defective = 3%)

Process average %	0–0.03			0.04–0.30			0.31–0.60			0.61–0.90			0.91–1.20			1.21–1.50		
Lot size	*n*	*c*	AOQL %	*n*	*c*	AOQL %	*n*	*c*	AOQL %	*n*	*c*	AOQL %	*n*	*c*	AOQL %	*n*	*c*	AOQL %
1–40	All	0	0	All	0	0	All	0	0	All	0	0	All	0	0	All	0	0
41–55	40	0	0.18	40	0	0.18	40	0	0.18	40	0	0.18	40	0	0.18	40	0	0.18
56–100	55	0	0:30	55	0	0.30	55	0	0.30	55	0	0.30	55	0	0.30	55	0	0.30
100–200	65	0	0.38	65	0	0.38	65	0	0.38	65	0	0.38	65	0	0.38	65	0	0.38
201–300	70	0	0.40	70	0	0.40	70	0	0.40	110	1	0.48	110	1	0.48	110	1	0.48
301–400	70	0	0.43	70	0	0.43	115	1	0.52	115	1	0.52	115	1	0.52	155	2	0.54
401–500	70	0	0.45	70	0	0.45	120	1	0.53	120	1	0.53	160	2	0.58	160	2	0.58
501–600	75	0	0.43	75	0	0.43	120	1	0.56	160	2	0.63	160	2	0.63	200	3	0.65
601–800	75	0	0.44	125	1	0.57	125	1	0.57	165	2	0.66	205	3	0.71	240	4	0.74
801–1,000	75	0	0.45	125	1	0.59	170	2	0.67	210	3	0.73	250	4	0.76	290	5	0.78
1,001–2,000	75	0	0.47	130	1	0.60	175	2	0.72	260	4	0.85	300	5	0.90	380	7	0.95
2,001–3,000	75	0	0.48	130	1	0.62	220	3	0.82	300	5	0.95	385	7	1.0	460	9	1.1
3,001–4,000	130	1	0.63	175	2	0.75	220	3	0.84	305	5	0.96	425	8	1.1	540	11	1.2
4,001–5,000	130	1	0.63	175	2	0.76	260	4	0.91	345	6	1.0	465	9	1.1	620	13	1.2
5,001–7,000	130	1	0.63	175	2	0.76	265	4	0.92	390	7	1.1	505	10	1.2	700	15	1.3
7,001–10,000	130	1	0.64	175	2	0.77	265	4	0.93	390	7	1.1	550	11	1.2	775	17	1.4
10,001–20,000	130	1	0.64	175	2	0.78	305	5	1.0	430	8	1.2	630	13	1.3	900	20	1.5
20,001–50,000	130	1	0.65	225	3	0.86	350	6	1.1	520	10	1.2	750	16	1.4	1,090	25	1.6
50,001–100,000	130	1	0.65	265	4	0.96	390	7	1.1	590	12	1.3	830	18	1.5	1,215	28	1.6

n = size of sample; entry of "All" indicates that each piece in lot is to be inspected.

c = allowable defect number for sample.

AOQL = average outgoing quality limit.

SOURCE: Bell Telephone Laboratories, Inc., and H. F. Dodge and H. G. Romig: *Sampling Inspection Tables*, John Wiley & Sons, Inc., New York, 1944, p. 71.

16-11. It must be remembered that applying the Dodge-Romig system provides a great variety of tolerance plans using both single and double sampling methods for lot tolerance per cent defective and for AOQL.

The lot-tolerance tables for both single and double sampling are classified according to lot tolerance per cent defective p_t at a consumer risk P_c of 0.01. These tables provide for tolerance plans ranging from 0.5 to 10.0 per cent defective. The primary objective of this type of plan is to give assurance that individual lots of unsatisfactory quality will rarely be accepted. Exhibit 16-10 presents a 3 per cent lot-tolerance single-sampling plan. It is assumed that with the consumer's risk P_c of 10 per cent, a person receiving the product has 1 chance in 10 of accepting a lot which has exactly 3 per cent unsatisfactory items. The process average percentage, computed from recent records of the particular manufacturing process, or estimated on the basis of economically attainable objectives, serves as one of the determining factors.

Lot size is another important variable. The figures in the lot-size column show that this particular table can be used for lots ranging in size from 1 to 100,000. The remaining six columns, labeled "process average percentage," provide an important base for further analysis. For example, the first column deals with processes which in the recent past had lot-tolerance per cent defectives averaging from no defectives to 0.03 per cent defective. Such a process would yield a very satisfactory product. At the other extreme, column 6 pertains to processes which average between 1.21 and 1.50 per cent lot-tolerance defective. The three subcolumns within each of the six process-average-percentage columns tell, in order, how many items out of each lot should be inspected (n), and how many defects (c) are permissible within the sample (n). The third of these subcolumns, labeled "AOQL %," refers to the AOQL, that is, the limiting percentage of defective product acceptable in the long run.

The procedure in using this table for single-sample inspection, lot-tolerance per cent defective, involves:

1. Determining the size of the lot N.

2. Selecting the proper size sample n, as designated on the chart.

3. Checking the number of defects c in the sample n.

4. Passing the entire lot if the number of defects does not exceed the permissible number of defects for the selected sample as shown in column c.

5. When the number of defects is in excess of the figure in column c, then all the items in the lot should be inspected. All defective units

Exhibit 16-11. Dodge-Romig Double-sampling AOQL Table

(Average outgoing quality limit = 2.0%)

Process average %	0–0.04						0.05–0.40						0.41–0.80					
	Trial 1		Trial 2				Trial 1		Trial 2				Trial 1		Trial 2			
Lot size	n_1	c_1	n_2	n_1+n_2	c_2	p_t %	n_1	c_1	n_2	n_1+n_2	c_2	p_t %	n_1	c_1	n_2	n_1+n_2	c_2	p_t %
1–15	All	0	—	—	—	—	All	0	—	—	—	—	All	0	—	—	—	—
16–50	14	0	—	—	—	13.6	14	0	—	—	—	13.6	14	0	—	—	—	13.6
51–100	21	0	12	33	1	11.7	21	0	12	33	1	11.7	21	0	12	33	1	11.7
101–200	24	0	13	37	1	11.0	24	0	13	37	1	11.0	24	0	13	37	1	11.0
201–300	26	0	15	41	1	10.4	26	0	15	41	1	10.4	29	0	31	60	2	9.1
301–400	26	0	16	42	1	10.3	26	0	16	42	1	10.3	30	0	35	65	2	9.0
401–500	27	0	16	43	1	10.3	30	0	35	65	2	9.0	30	0	35	65	2	9.0
501–600	27	0	16	43	1	10.3	31	0	34	65	2	8.9	35	0	55	90	3	7.9
601–800	27	0	17	44	1	10.2	31	0	39	70	2	8.8	35	0	60	95	3	7.7
801–1000	27	0	17	44	1	10.2	32	0	38	70	2	8.7	36	0	59	95	3	7.6
1001–2000	33	0	37	70	2	8.5	33	0	37	70	2	8.5	37	0	63	100	3	7.5
2001–3000	34	0	41	75	2	8.2	34	0	41	75	2	8.2	41	0	84	125	4	7.0
3001–4000	34	0	41	75	2	8.2	38	0	62	100	3	7.3	41	0	89	130	4	6.9
4001–5000	34	0	41	75	2	8.2	38	0	62	100	3	7.3	42	0	88	130	4	6.9
5001–7000	35	0	40	75	2	8.1	38	0	62	100	3	7.3	44	0	116	160	5	6.4
7001–10,000	35	0	40	75	2	8.1	38	0	62	100	3	7.3	45	0	115	160	5	6.3
10,001–20,000	35	0	40	75	2	8.1	39	0	66	105	3	7.2	45	0	115	160	5	6.3
20,001–50,000	35	0	40	75	2	8.1	43	0	92	135	4	6.6	47	0	148	195	6	6.0
50,001–100,000	35	0	45	80	2	8.0	43	0	92	135	4	6.6	85	1	185	270	8	5.2

Process average %	0.81–1.20						1.21–1.60						1.61–2.00					
	Trial 1		Trial 2				Trial 1		Trial 2				Trial 1		Trial 2			
Lot size	n_1	c_1	n_2	n_1+n_2	c_2	p_t %	n_1	c_1	n_2	n_1+n_2	c_2	p_t %	n_1	c_1	n_2	n_1+n_2	c_2	p_t %
1–15	All	0	—	—	—	—	All	0	—	—	—	—	All	0	—	—	—	—
16–50	14	0	—	—	—	13.6	14	0	—	—	—	13.6	14	0	—	—	—	13.6
51–100	21	0	12	33	1	11.7	21	0	12	33	1	11.7	23	0	23	46	2	10.9
101–200	27	0	28	55	2	9.6	27	0	28	55	2	9.6	27	0	28	55	2	9.6
201–300	29	0	31	60	2	9.1	32	0	48	80	3	8.4	32	0	48	80	3	8.4
301–400	33	0	52	85	3	8.2	33	0	52	85	3	8.2	36	0	69	105	4	7.6
401–500	34	0	56	90	3	7.9	36	0	74	110	4	7.5	60	1	90	150	6	7.0
501–600	35	0	55	90	3	7.9	37	0	78	115	4	7.4	65	1	95	160	6	6.8
601–800	38	0	82	120	4	7.3	38	0	82	120	4	7.3	70	1	120	190	7	6.4
801–1000	38	0	87	125	4	7.2	70	1	100	170	6	6.5	70	1	145	215	8	6.2
1001–2000	43	0	112	155	5	6.5	80	1	160	240	8	5.8	110	2	205	315	11	5.5
2001–3000	75	1	115	190	6	6.1	115	2	195	310	10	5.3	160	3	310	470	15	4.7
3001–4000	80	1	140	220	7	5.8	120	2	255	375	12	5.0	235	5	415	650	20	4.3
4001–5000	80	1	175	255	8	5.5	125	2	285	410	13	4.9	275	6	475	750	23	4.2
5001–7000	85	1	205	290	9	5.3	125	2	320	445	14	4.8	280	6	575	855	26	4.1
7001–10,000	85	1	210	295	9	5.2	165	3	335	500	15	4.5	320	7	645	965	29	4.0
10,001–20,000	90	1	260	350	11	5.1	170	3	425	595	18	4.4	395	9	835	1230	37	3.9
20,001–50,000	130	2	300	430	13	4.7	205	4	515	720	22	4.3	480	11	1090	1570	46	3.7
50,001–100,000	135	2	345	480	14	4.5	250	5	615	865	26	4.1	580	13	1460	2040	58	3.5

n_1 = size of first sample; n_2 = size of second sample; entry of "All" indicates that each piece in lot is to be inspected.

c_1 = allowable defect number for first sample; c_2 = allowable defect number for first and second samples combined.

p_t = lot tolerance per cent defective corresponding to a consumer's risk $(P_c) = 0.10$.

SOURCE: Bell Telephone Laboratories, Inc., and H. F. Dodge and H. G. Romig: *Sampling Inspection Tables,* John Wiley & Sons, Inc., New York, 1944, p. 95.

should be eliminated prior to passing the lot to the next operation or to the consumer.

As a simple illustration, if past records indicate a process average of 0.56 per cent defective product and the lot size is 900, then the appropriate sample size is 170. In this sample there should be no more than two defectives. The AOQL would in this instance be 0.67 per cent. However, if the lot size is 100,000, then a sample of 390 items should be selected with a maximum of 7 defects permissible. On the other hand, assuming a process average of 1.35 defective product and lot sizes of 100,000, samples of 1,215 items should be selected with permissible defects of 28 items per sample.

The lot-tolerance plans are particularly usable in cases where the lots retain their identity after inspection and until they are received and put to use in the subsequent manufacturing or consumption phases. These plans emphasize a low consumer risk ($P_c = 0.01$) with varying average outgoing quality limits. Thus these plans give assurance that individual lots of poor quality will very seldom be accepted.

The AOQL tables, on the other hand, are intended to set the long-run average quality limit. This means that individual lots of poor quality might occasionally be passed. One of the very important cautions in using the AOQL tables, and also the AOQL percentage subcolumns in the lot-tolerance tables, is the importance of inspecting all rejected lots by the 100 per cent inspection technique. The results of this 100 per cent inspection must be included in the calculations. It is this averaging effect of the relatively perfect quality resulting from detail or 100 per cent inspection, with the poorer quality of the less perfect lots occasionally accepted because of the postulated 10 per cent consumer-risk factor (P_c), which sets the AOQL. Consequently, AOQL plans are questionable as to value when rejected lots are cast aside without recourse to 100 per cent inspection.

The AOQL plan presented in Exhibit 16-11 is for double sampling and assures an AOQL of 2 per cent. This technique places emphasis on the maximum average fraction defective in the flow of product, after inspection, which will not be exceeded regardless of the qualitative variations in individual lots.

The double-sampling procedure used in both lot tolerance per cent defective inspection or in AOQL inspection provides for the selection of a second sample n_2 from the lot if the first sample n_1 exceeds the prescribed permissible defects per sample as specified in column c_1.

Acceptance or rejection under these conditions hinges upon:

1. Determining the size of the lot N.

2. Selecting the proper size sample n_1 for the initial test.

3. Checking the number of defects c_1 in this first sample n_1.

4. Passing the entire lot if the number of defects does not exceed the limit as shown in column c_1.

5. If the number of defects for sample n_1 exceeds the maximum permissible, as shown in column c_2, then the entire lot must be subjected to 100 per cent inspection.

6. If the number of defects in the sample n_1 is in excess of the column c_1 figure but does not exceed the comparable column c_2 figure, then a second sample n_2 should be selected. The size of this second sample for various lot sizes is listed in column n_2.

7. If the combined number of defects in samples $n_1 + n_2$ does not exceed the c_2 figure, then the lot should be accepted.

8. When the number of defects in $n_1 + n_2$ is greater than the c_2 figure, then the remainder of the lot should be 100 per cent inspected.

Exhibit 16-11 provides an illustration of a 2 per cent AOQL double-sampling plan. Assuming lot sizes of 900 and a process average percentage of 0.56, a first sample, n_1, of 36 items should be selected. There should be no defects, as shown in column c_1, if the lot is to be immediately accepted. In the event that this sample should contain more than 3 defectives, the entire lot should be 100 per cent inspected. This limit is indicated in column c_2. If there are up to 3 defects in n_1, then a second sample, n_2, should be chosen. The combined defects in samples $n_1 + n_2$ should still not exceed 3; otherwise the remainder of the lot should be subjected to 100 per cent inspection.

In the extreme lower-right-hand corner of the exhibit are comparable figures for lots ranging from 50,000 to 100,000 units and an assumed process average of 1.61 to 2.00 defectives. In such a situation the initial sample n_1 should include 580 items with the first acceptance level set at 13 defects and the rejection point at 58 defects. If, for example, the first sample n_1 should contain 21 defects, then selection of the second sample n_2 is necessary. Assuming n_2, which numbers 1,460 items, contains 30 defects, then $n_1 + n_2$, or $580 + 1{,}460 = 2{,}040$ items inspected. The total defects $= 21 + 30$, or 51. This is within the maximum acceptance limit of 58; consequently the lot is passed. If the samples had had 8 additional defective items, then the remainder of the lot would have been subject to 100 per cent inspection.

Double-sampling procedure, although in this instance specifically designed for AOQL sampling, is equally usable in lot-tolerance per cent defective inspection. In either case the quality control policy maker must decide whether or not it is economic to resort to taking a second sample when there are some doubts as to the quality level

of a particular lot. Usually double sampling is economic when the process-average-quality level is so good that resorting to a second sample is required infrequently. Too frequent a recourse to a second sample prior to making a decision as to acceptance or rejection of the lot can, obviously, become time-consuming and costly if the average quality is relatively poor. On the other hand, single sampling can likewise be costly if too many lots are subjected to 100 per cent sampling. For example, using the 3 per cent lot-tolerance per cent defective table, if a lot of 3,000 items for a process average of 0.029 is being analyzed, a sample of 75 units should be selected. None of these 75 sample items can be defective; otherwise the remaining 2,925 items in the lot must be individually inspected. Both techniques have specific advantages. On the whole double sampling seems to be less commonly used because of its relative complexity and particularly because of the difficulty in selecting an independent second sample.

TECHNIQUE 3. Operating Characteristics (OC) Curves

It is logical to assume that even after choosing and applying a specific inspection plan there will be some good lots that are rejected and some bad lots which escape detection. Then too, some of the lots will be only very slightly below or very slightly above the breaking point. It is important, consequently, to know the probability of acceptance P_a for lots coming from processes with an incidence of a given fraction defective p. The p factor, as previously mentioned, is determined from an analysis of performance records or is estimated tentatively and then is revised as operating data become available.

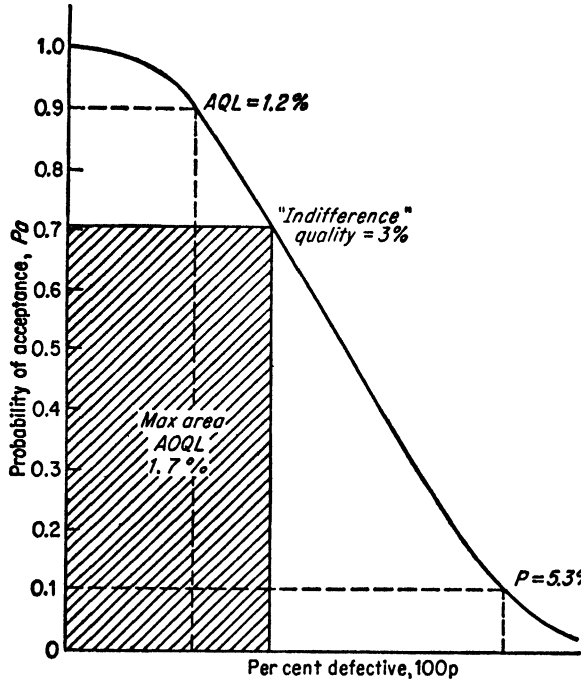
The probabilities of acceptance can be computed by a number of methods, all of which are rather complex, being based upon advanced statistics. Generally, the operating-characteristic curves are derived by means of the binomial or the Poisson approximation. In every instance it is assumed that the probability of acceptance P_a refers to the long-run percentage which would be accepted from a great number of lots submitted for inspection.

Exhibit 16-12 shows, in graphic form, how a decision maker can use one version of the OC curve. In this hypothetical case a sample n of 150 items is selected from a lot N of 3,000. A maximum of four defectives in the sample is permissible in this instance so that quality of a desired level will be assured. Obviously, the incidence of defectives per sample varies inversely with the degree of perfection present in the lot. If the lot fraction defective is 0.01, then the total number of defectives in the lot is 30. The sample of 150 taken from the lot can contain all, part, or none of these 30 defectives. Consequently, knowl-

edge of probability theory is of great importance in determining the odds that selected samples will contain a specified number of defectives.

The vertical scale in Exhibit 16-12 measures the probability that a lot with a per cent defective, as indicated on the horizontal scale, will be accepted. In this particular graphic presentation a lot with 5 per cent defective items has 1 chance in about 12 of being accepted.

Exhibit 16-12. A Sampling Plan



SOURCE: J. M. Juran (ed.), *Quality Control Handbook,* McGraw-Hill Book Company, Inc., New York, 1951, p. 416.

The probabilities of acceptance for 4, 3, 2, and 1 per cent defective lots are about 27, 50, 80, and 97 per cent, respectively.

It can readily be inferred from this chart that despite the most advanced techniques in production technology, absolute control as to quality is attainable only at prohibitive costs. The availability of numerous per cent defective–probability-of-acceptance combinations should focus emphasis upon the limitations inherent in what generally is assumed to be the scientific application of sampling technique. In

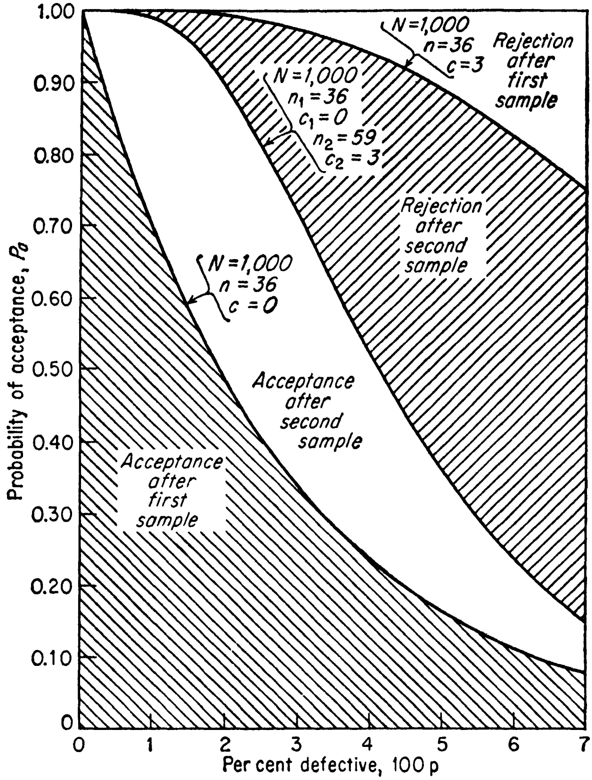
this particular sampling plan even a 3 per cent defective lot has a 50–50 probability of being accepted. If 3 per cent defective has been set as the maximum permissible, then even a 5 per cent defective lot has a probability of acceptance (P_a) of about 12 per cent, or 1 chance in 8. The probability of acceptance of lots with a quality approximating the breaking point is particularly interesting. Thus with 3.1 per cent defective there is a probability that in about 48 chances out of 100 a "bad" lot will be accepted. On the other hand, a 2.9 per cent defective lot has about 52 chances out of 100 of being accepted.

It must be remembered that the operating-characteristic curve shown in Exhibit 16-12 is simply one version, determined by the size of the lot, the size of the sample, the lot tolerance per cent defective, the number of defectives permissible in the sample, and the probabilities of acceptance. Modifications in any of these parameters or variables necessarily result in curve variations. Thus a great variety of OC curves can be drawn, depending upon manufacturing methods, quality control techniques, consumer preferences, cost considerations, and other less relevant internal and external circumstances.

The projection of OC curves in double sampling is considerably more complex. Exhibit 16-13 shows, in graphic form, the characteristics of a typical double-sampling plan. It must be kept in mind that in double sampling relatively stringent requirements are set for acceptance on the basis of the first sample. In this particular example no defective items are permissible in a sample of 36 taken from a lot of 1,000. On the other hand, the limit for outright rejection of the lot on the basis of the first sample alone is relatively wide. The lot will be rejected only if more than three defective items are found in the first sample. In the event that the sample of 36 items contains one, two, or three defectives, then a second sample, in this case $n_2 = 59$, must be taken. If the combined defectives in n_1 and n_2 are still three or less, then the lot is passed. More than three defectives in the combined samples means outright rejection of the lot, or 100 per cent inspection.

In general OC curves have the benefits associated with any form of graphic presentation. Tables and equations can easily become complicated and even unintelligible. Graphic portrayal, on the other hand, generally contains a summary of vital factors. This succinctness permits facility in conveying otherwise unwieldy information and ideas. The modern industrial administrator can scarcely be expected to become proficient in all the technical areas pertinent to effective corporate performance. An acquaintance with short-cutting devices, such as the OC curves, should be of immeasurable value to the executive. Through

Exhibit 16-13. Characteristics of a Double-sampling Plan



SOURCE: E. L. Grant, *Statistical Quality Control,* McGraw-Hill Book Company, Inc., New York, 1952, p. 327.

this type of rudimentary technical competency the policy implementor and the policy formulator can more readily make meaningful decisions based upon a higher level of scientific management.

TECHNIQUE 4. Control Charts for Variables: $\bar{X}$ and R Charts

The average workman is not only limited in his knowledge of statistics, but he also generally has a suspicion of and an aversion to the direct application of such theoretical tools to the work place. A very useful device to minimize such worker reluctance is to transform elaborate calculations into relatively concise graphic presentations. In the sphere of quality control, there are a variety of charts which perform this function. The $\bar{X}$ and R charts are most commonly used when

the control of quality pertains to variance in degree, dimension, intensity, etc. The procedure in this type of graphic presentation consists of the following steps:

1. Determine how many items should be inspected so that valid conclusions can be inferred.

2. Divide the sample into small subgroups. These subgroups should be selected from the process in a sequential pattern. Subgroups of either 4, 5, or 6 are most commonly chosen.

3. Compute the arithmetic mean $\bar{X}$ for each subgroup.

4. Compute the range R for each subgroup.

5. Calculate the arithmetic mean $\bar{\bar{X}}$ of the subgroup arithmetic means.

6. Using the formula $\bar{\bar{X}} \pm A_2R$, set upper and lower control limits. The value for A_2 can be obtained from Exhibit 16-14. For subgroups of five items, this value is 0.577.

Exhibit 16-14. Factors for Determining Three-sigma Control Limits, for $\bar{X}$ and R Charts

Subgroup size	Factor for $\bar{X}$ chart	Factors for R chart	
n	A_2	D_3	D_4
2	1.880	0	3.268
3	1.023	0	2.574
4	0.729	0	2.282
5	0.577	0	2.114
6	0.483	0	2.004
7	0.419	0.076	1.924
8	0.373	0.136	1.864
9	0.337	0.184	1.816
10	0.308	0.223	1.777
.	.	.	.
.	.	.	.
.	.	.	.
15	0.223	0.348	1.652

SOURCE: *ASTM Manual on Quality Control of Materials,* STP 15-C, 6th Printing, American Society for Testing Materials, Philadelphia.

7. Determine comparable upper and lower control limits for the range R by use of the formulas D_4R and D_3R. The D_4 and D_3 values

for subgroups of five items, as shown in Exhibit 16-14, are 2.114 and 0, respectively.

8. Draw the grand averages $\bar{\bar{X}}$ and $\bar{R}$ as lines on separate charts.

9. Plot the subgroup arithmetic means $\bar{X}$, and ranges, R on the respective charts.

10. Draw the upper and lower trial control limits as computed in steps 6 and 7.

11. Note the items that exceed the permissible limits.

12. Find the causes responsible for the excessive deviations.

13. Initiate corrective action.

The following is a simple-arithmetic illustration of these basic steps:

Exhibit 16-15

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
	2.131	2.166	2.182	2.001	2.098
	2.101	2.092	2.112	2.012	1.939
	2.252	2.004	2.011	2.158	2.103
	2.077	2.016	2.127	2.171	2.012
	2.079	2.100	2.034	2.196	2.184
$\Sigma =$	10.6400	10.3780	10.4660	10.5380	10.3360
$\bar{X} =$	2.1280	2.0756	2.0932	2.1076	2.0672
$R =$	0.1750	0.1620	0.1710	0.0195	0.2450

Sample 1.	2.1280	0.175	
Sample 2.	2.0756	0.162	
Sample 3.	2.0932	0.171	
Sample 4.	2.1076	0.195	Drawing dimension: 2.100 ± 0.100
Sample 5.	2.0672	0.245	Lower limit: 2.000
			Upper limit: 2.200
$\Sigma =$	10.4716	0.948	
$\bar{\bar{X}} =$	2.09432		
$\bar{R} =$		0.1896	

From the preceding calculations it is evident that the measure of central tendency $\bar{\bar{X}}$ is 2.09432. The five subgroup arithmetic means $\bar{X}$ will be scattered on either side of this arithmetic mean of the subgroup means. Determination of upper and lower control limits for the arithmetic mean is facilitated by use of the commonly accepted formulas:

$UCL_{\bar{X}} = \bar{\bar{X}} + A_2R$, or $2.09432 + (0.577 \times 0.1896) = 2.09432 + 0.1094$

$= 2.20372$

$LCL_{\bar{X}} = \bar{\bar{X}} - A_2R = 2.09432 - 0.1094$

$= 1.98492$

Comparable formulas are used to calculate permissible upper and lower limits for the range:

$$UCL_R = D_4\bar{R} = 2.114 \times 0.1896 = 0.4008$$

$$= D_3\bar{R} = 0 \times 0.1896 = 0$$

The results of these calculations are succinctly presented in Exhibit 16-16.

In this particular example all the subgroup means $\bar{X}$ and range values R fall well within the computed trial control limits. The immediate reaction would be to conclude that this process is in control. However, caution should be used in making such inferences. For practical purposes the data in this example warrant acting on the hypothesis that no assignable causes of variation are present. However, there is no statistical test which can yield absolute assurance. The figures in the sample subgroups have purposely been so set that out of the total of 25 sample items, 2 actually exceed the computed trial control limits. Thus, while the five subgroup means fall within the prescribed limits, there is still a probability that some of the individual items within the subgroups will be defective. Although the control chart device is a valuable adjunct for quality control purposes, it is subject to:

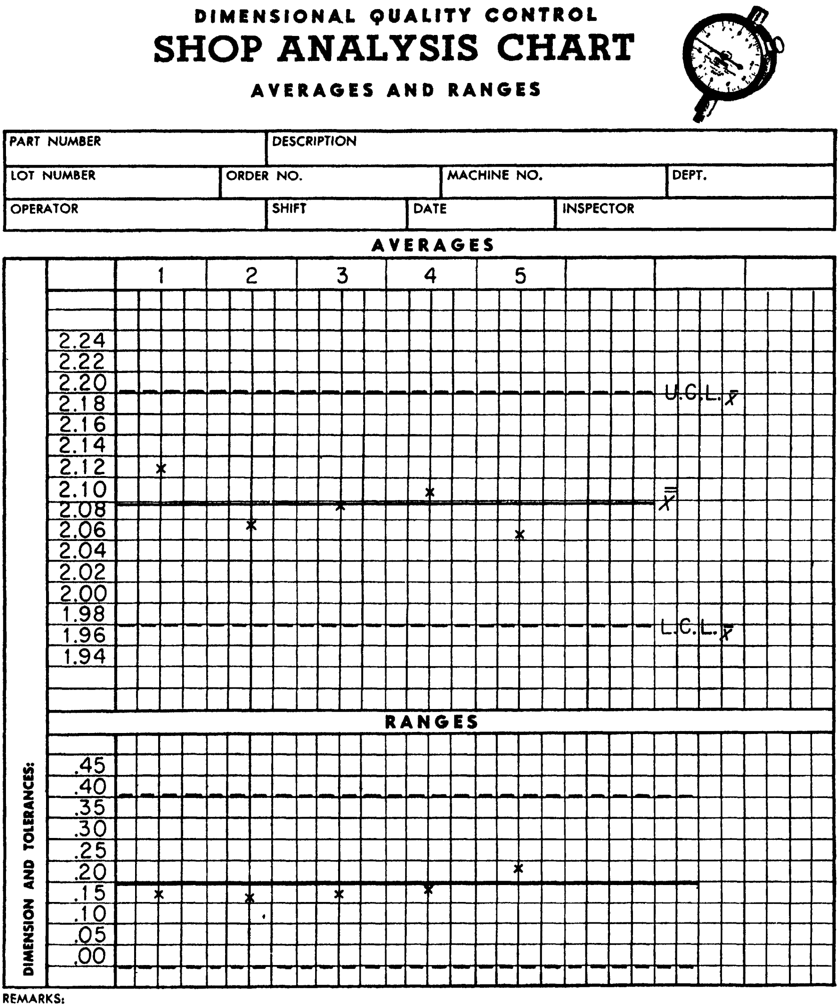
1. The rigidity or looseness with which limits are set
2. The exactness of actual measurement or observation
3. The realization that, despite all human effort, there is still a probability that some defective items will be included

This description of the $\bar{X}$ and R charts of necessity presents only a few of the highlights relating to industrial quality control charts. In addition to the two types of charts mentioned, there are at least four other major methods of control charting. These include:

1. p charts, pertaining to the fraction defective
2. c charts, dealing with the number of defects
3. np charts, measuring the number of defects
4. σ charts, using the standard deviation for control purposes

Each type of chart has its own specific advantages and limitations. For example, $\bar{X}$ and R charts can be used to great advantage where the characteristic being studied can be compared along a scale of

Exhibit 16-16. $\bar{X}$ *and* R *Control Charts*



measurement. Where such a calibrated measuring scale cannot be used, as for example in go–no-go gauging, then *p* or *c* charts should be used. The ***X***, ***p***, and *c* charts all are concerned with the prevailing level of quality, while the *R* chart deals with degree of uniformity in the items tested. The σ chart performs a similar function and is preferable to the *R* chart when the subgroups are large or when expensive or destructive tests make mandatory the minimizing of testing. The *np* chart, since it converts the fraction defective into more readily

comprehended terms, is thus sometimes preferable to the p chart.

The technique as set forth in the preceding illustration is based upon three-sigma limits. This means that there is a statistical probability that only about 27 items in a universe of 10,000 will fall outside the range as set by the formulas $\bar{\bar{X}} + A_2R$, D_4R, and D_3R. Although three-sigma control limits are the most frequently used for quality control charting purposes, it is also possible to use probability limits. For example, it might be desirable to have the quality of a given level so that there is a probability of only 0.025 that an item measurement exceeds the limit and a similar probability of 0.025 that the item falls short of reaching the minimum dimension. Thus there is a total probability of 0.05 that an item does not meet specifications. The use of probability limits, while popular in British industry, is rather infrequent in the Uñited States.

It must also be kept in mind that control limits determined statistically are not always identical with specification limits. For example, the specifications as indicated by the drawing dimensions in the preceding example were 2.100 ± 0.100. The three-sigma control limits, on the other hand, were computed as 2.09432 ± 0.1094. This would indicate that the specifications were slightly less rigid than the statistical control limits. Thus a process in control statistically would still tend to have about 27 items out of every 10,000 failing to meet the standards. However, the broader tolerance of the specifications would, in this case, practically assure that a process in control statistically would yield very few defective items.

This illustration of control charting, together with the other examples of technical quality control devices as set forth in this chapter, is at best a fragmentary presentation. The importance of a better grooming in statistical technique should be obvious to any would-be manager. However, the emphasis on complex methodology should not be construed as the basic function of quality control. In the industrial process, quality control is simply one of a number of devices by means of which the decision maker can more effectively attain the organization's goals, which include producing a better product at a lower price, guaranteeing the quality of that product, predetermining desired quality levels, and pointing out where processes should be adjusted for higher-quality output.

ILLUSTRATION 1. Quality Control Audit

The Ford Division of the Ford Motor Company announced late in 1957 that, consistent with its policy of striving for top quality in its product, the company was embarking on what it termed a quality

control audit program. This program is used in addition to the conventional quality control techniques generally employed in mass-production industries. The differentiating features of the new program include the establishment of teams of specially trained inspectors who pick at random several cars that have already been passed through the assembly line. The inspection team then gives each selected car an intensive checking. Poor workmanship is traced back to the workmen, supervisors, and inspectors responsible. These individuals are then notified of the unsatisfactory product. Each audit takes approximately three hours of inspection time, during which about 1,500 items are checked.

The logic for this intensive inspection is based upon the assumption that designating individual responsibility as to the quality of a mass-produced item engenders pride of workmanship. Presumably this differentiation and allocation of responsibility would do much to counteract the "leveling tendency" of mass-production industries wherein the individual's contribution appears insignificant in relationship to the product of group effort. Noticing an individual workman's product, it is believed, will stimulate him to do a better job.

QUESTIONS

1. Is this technique a variant of acceptance sampling?
2. To what extent would intensive inspection be justified on a cost basis?
3. Would a more detailed inspection plan for control of quality at the work stations make this type of quality control audit superfluous?

ILLUSTRATION 2. Lamb Electric Company—*X* and *R* Charts

The Lamb Electric Company of Kent, Ohio, makes a great variety of fractional-horsepower motors. Some of the orders include only two or three items, while occasionally an order is received for several thousand motors of one style and size. Obviously, random-sampling techniques can be employed only in those instances where the operation is sufficiently repetitive and the component is rigidly standardized. Most of the very large orders, specifically those involving mass-production-type operations, are performed at Lamb Electric's Cambridge, Ohio, line-layout plant. Where feasible, the company uses statistical quality control techniques.

The following data refer to the random sampling and checking of a specific dimension on a component known as a field core. This dimension refers to the inside measurement of a hole punched in the component field core. In the inspection process, samples of five items are taken at random intervals during the work day. These samples are taken directly after the punch-press operation. Variance is per-

Exhibit 16-17. Data on 16 Random Samples of a Dimension on a Field-core Component

Sample	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Time	A.M. 7:30	7:55	8:10	8:40	9:00	9:45	10:15	10:45	11:10	11:50	P.M. 12:50	1:20	1:40	2:05	2:30	3:15
	22	23	24	23	19	23	24	24	21	21	21	20	20	19	23	19
	23	25	25	20	22	22	20	24	22	20	21	22	21	22	20	23
	24	25	24	19	20	23	23	24	23	19	21	19	20	23	19	22
	24	25	25	19	20	23	24	25	21	20	22	19	23	23	19	23
	27	27	21	19	19	19	24	22	23	20	20	20	21	23	19	23
$\bar{X}$																
R																

CAUTION: The figures as shown above refer to the last two digits of the measurement. Thus 22 should actually read 1.422, 19 refers to 1.419, etc.

missible on an over-all basis, from a minimum dimension of 1.416 to a maximum dimension of 1.427 inches. However, this dimension must not vary more than 0.004 inch in any one core at specified points. In the sample subgroups, the maximum variance in the range has been set at 0.005 inch. Sixteen samples of five units each were taken in the course of a given day. These data are shown in Exhibit 16-17 and are plotted on the dimensional quality control shop analysis chart.

QUESTIONS

1. Compute $\bar{X}$, $\bar{\bar{X}}$, and R.
2. Using the formulas for $UCL_{\bar{x}}$ and $LCL_{\bar{x}}$, what inferences can you make?
3. Is the process in control?

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CHAPTER 17

Job Evaluation

DEFINITION AND DESCRIPTION

Of all the techniques used in industrial organization probably the most important are those immediately associated with the integration of human beings into an organization structure. The basic principles pertinent to this topic were partially analyzed in Chapter 5, which dealt with the concept of organization structure. This present chapter is concerned with several of the more commonly used methods for implementation of the philosophies, policies, and principles enunciated in Chapter 5.

It would be repetitious to set forth, at this point, the entire sequence by which an administrator makes decisions as to the specific positions and jobs which are to be part of the organization structure. Not only must he decide upon the specific positions, he must also identify with great precision the exact authority and responsibilities inherent in each position, the relationships among jobs, and the manner in which the jobs are integrated into a joint organizational endeavor. The very hierarchical nature of organization demands that a logical progression of positions and jobs be made on the basis of relative difficulty and importance. Finally, since the ultimate objective of all organization is individual satisfaction, there must be an equitable pricing of all positions and jobs.

Before a rational sequence of positions or of jobs on the basis of importance can be ventured, it is first necessary to agree upon what

constitutes such positions and jobs. In essence a job entails a readily distinguishable and continuing group of activities requisite to the performance of one phase of organizational endeavor. Fundamentally, the job should encompass a group of very intimately related operations or tasks requiring an easily identifiable skill or competency. Although many authorities endeavor to differentiate between a position and a job, such differentiation tends to be semantic. Consequently, it is deemed expedient to avoid hairsplitting and, at least in this chapter, to assume an identity of the terms *position* and *job*.

Moreover, the lines of demarcation among jobs frequently tend to become ephemeral. Even where great care has been taken to spell out very carefully all the duties and rights encompassed within a specific job, disagreement and confusion can easily arise. Technological changes, modifications in custom, pressures from forces such as trade unions, shifts in management philosophy, and similar factors frequently necessitate revamping job content and title. On the other hand, the *status quo* mentality tends to resist all modifications, particularly if there is even the slightest suspicion of job downgrading.

In the interests of effective organization control it is very important to prevent the number of jobs from being multiplied simply as a measure of expediency. This occurs when every minor operational difference is translated into a new job title. Neither should the opposite approach of incorporating too many widely divergent activities into a single job be followed. It is the function of the decision maker to determine when a group of related duties and activities becomes sufficient from an intensive and an extensive point of view to be designated as a separate job. He must, likewise, decide upon the appropriate modifications to be incorporated as time and technological change dictate.

The job-evaluation process can be considered as a means by which questions such as the following are answered.

1. What is the basic function or functional component which is sufficiently important to the organization to warrant designation as a job?
2. What are the corollary activities which can logically and readily be attached to this job?
3. What is the sequence in which these various job components should be performed?
4. What is the proportion of the working day to be allocated to each of these job duties?
5. What is the relative difficulty of these individual duties?
6. What is the relative difficulty of the composite job in comparison with all other jobs within the organization?

7. Finally, what is the worth of the job to the organization?

Terms closely associated with job-evaluation procedure include job analysis, job description, and job specification. Job analysis is fundamentally a breaking down of the job into its components. This breakdown is accomplished by studying the job and noting what activities are requisite for completion of all the tasks encompassed within the job. The analysis invariably begins with the collecting of pertinent facts. Since such collection is simply the first phase in the scientific process, it is imperative that these facts be systematically arranged and properly put to use. This analytical procedure should ferret out all important information from every available source. Consequently, if the job analysis is to be effective, not only are management representatives, particularly foremen, to be consulted but also the opinions of the workers themselves must be solicited. Frequently combining divergent views yields much more valid analyses.

Job description is generally considered to be the next step in this scientific procedure. If job analysis is the breaking down of a job into its component parts, then job description is the rebuilding of that job according to a standard procedure. This procedure generally calls for a written statement giving a detailed explanation of what constitutes the job. There is considerable variance in the exact procedure by which job description is carried out and also in the finished product. Fundamentally, however, in every case there is agreement as to a descriptive title together with a sentence, or preferably a paragraph or more, describing the important activities, tasks, functions, duties, responsibilities, operations, etc., encompassed within the job.

Although job description provides a means for systematic appraisal of an organization's job structure, it is generally not advisable to stop at this point. Sound logic dictates that, since the job has been broken down into its elements, the process of synthesizing can be expedited and made more effective if each element is individually identified as an integral part of the job. The most commonly applied method consists in the use of verbs to identify the important activity. For example, job *A* might consist of four basic activities:

Lift boxes	15 minutes
Carry boxes	17 minutes
Place boxes	8 minutes
Return to stockpile	12 minutes

Emphasizing the verb's task and placing it at a strategic position in the phrase or sentence facilitates reading and comprehension.

The next step in the scientific analysis of the job structure is to quantify the activities, preferably by determining the portion of an

hour or day dedicated to such activity. In the preceding example, a typical hour might be allocated among the four activities on the basis of 15, 17, 8, and 12 minutes per hour, respectively. It should be noticed that the sum of these figures is less than 60 clock minutes per hour. The difference could be ascribed to delay factors for personal or uncontrollable reasons.

This phase of the job-analysis-description procedure is, obviously, related to the methods-study techniques described earlier in the text. The next step, rewriting the job description so that the inherent duties are translated into component factors which facilitate quantification, is sometimes termed job specification. This phase leads logically to the selection of certain standard factors, such as formal education, experience, etc., as being requisite, in varying degrees, to all the jobs. These factors provide a common basis for comparison purposes. Obviously, if the more elemental activities such as lifting, carrying, etc., were to be used exclusively, the excessive number of items would seriously impede the final phases of the job-evaluation process.

While the job-analysis, job-description, and job-specification stages are important, they are essentially routine operations involving a minimum of policy making. On the other hand a comprehension of the job-evaluation function necessarily includes an appreciation of the subsidiary aspects. Consequently, this presentation of the preliminary job-evaluation steps is necessarily brief. Reference to company manuals dealing with job description should provide the interested student with a better comprehension of the scope and importance of this scientific-management device. *The Dictionary of Occupational Titles*,[1] which lists more than 23,500 job titles and descriptions, would probably provide an even better tangible source of reference material. Actually, as its name implies, it is an attempt at setting universal standards as regards job titles and job content. An acquaintance with this dictionary is the surest way to appreciate the complexity and vital significance of systematically and scientifically integrating jobs into an organization structure.

Up to this point the job-evaluation procedure has been concerned with:

1. Breaking down a job into its component parts
2. Systematically rearranging the job elements
3. Associating the job elements with specifically selected factors common, to some degree, to all the jobs studied
4. Describing the job in terms of these constant factors

The next step in the procedure is to determine a progression based

[1] U.S. Government Printing Office.

on job complexity. This evaluation of job difficulty, and hence of job importance, is essentially only an intermediate step. The ultimate objective of the entire process is to attach equitable compensation to each job. Equity demands that job pricing result in a wage structure which takes proper cognizance of the individual job's importance to the organization.

Basically there are four job-evaluation methods:

1. Job ranking
2. Job classification
3. Factor comparison
4. Point systems

An even more fundamental appraisal based upon the extent to which the procedure stresses scientific methodology could also be used. In this instance the first two methods, ranking and classification, are far less scientific than the latter two categories in so far as the jobs are not broken down into their component parts and quantification either is omitted or is of minor importance. Rather than label these first two categories as nonscientific, it seems preferable to designate them as nonquantitative techniques. The factor-comparison and point methods, because of the stress they place upon analyzing and comparing jobs on the basis of selected factors and elements and because of the quantified weights attached to factorial degrees, can be termed quantitative techniques.

TECHNIQUE 1. Nonquantitative Methods

Job Ranking. In its simplest form ranking consists in the alignment of jobs in their order of importance. The procedure is similar to the arranging of a deck of cards in a sequence from deuce to ace, or vice versa. As a rule this ranking of jobs in order of importance uses no numerical designation, except possibly the wage scale, for gradation purposes. Thus the procedure is almost entirely nonquantitative. As such, it easily becomes subjective and nonscientific. Yet it has considerable merit in that it is relatively simple and informal.

One of its serious limitations is the requirement that the raters have almost complete knowledge and information about the jobs in question. The knowledge and information usually come from the rater's intimate contact with the various jobs, from opinions of supervisors and others acquainted with the specific jobs, and from data already incorporated in job descriptions.

While ranking is simple to use, easy to comprehend, requires less paper work, and is the least costly of all job-evaluation methods, it also has limitations other than those already inferred. It is less ac-

curate than the other methods. In the ranking there is no indication of the differential in importance between jobs. Then too, as the number of jobs being ranked increases greatly, there is a disproportionate increase in complexity. The requisite intimate acquaintance of the rater with jobs being rated becomes difficult or even impossible to maintain. In addition to limiting the scope of analysis and raising the costs, this requisite close contact can also lead to an obvious bias. The rater can very easily associate the man and the job. Such association vitiates the job-evaluation process, which requires that only the jobs be compared. Injection of the manpower aspect can, at least at this point, completely spoil the equitable arranging of jobs. Judgment as to the worth of the *man* is essentially a matter for merit rating, a technique to be discussed later. In all fairness to the ranking method, it should be emphasized that the danger of such bias is also present in the other job-evaluation techniques.

Job Classification. This method of job evaluation, sometimes referred to as the grade-description technique, is practically identical with job ranking except for one fundamental difference. At specified levels in the job progression limits are set so that a number of classifications or grades are established. This use of grades or classes simplifies the job comparison, which can become onerous and most confusing if too great a number of jobs must be compared one with another. For example, if 100 different jobs were being ranked, then the progression in the ranking method would run from 1 to 100. The raters would invariably encounter difficulty in making so refined a differentiation. The ranking, even if completed, would have a limited use since few of those directly concerned could remember the precise ranking of all the jobs.

Job classification eliminates many of these and similar limitations. If the previously mentioned 100 jobs are assigned to one-tenth or even one-twentieth that number of classifications, then the basic simplicity of ranking is preserved despite the large number of jobs. Generally, once classification is accepted, a careful definition must be set forth prescribing minimum, and sometimes also maximum, requirements for each class. These basic requirements for each classification can then be considered as norms, or standards. If standards are properly defined, it becomes relatively easy to take any new or revised job and place it in its proper category by simply comparing it with the prescribed classification standards.

Generally, minimum and maximum pay rates are prescribed for each job class. The procedure for progression from minimum to maximum pay rates within a given class and for movement from one class

to another is usually set forth in detail. Nevertheless, the difficulty in delineating precise boundaries between job classes frequently leads to considerable overlapping.

The number of levels to be used is also a source of controversy. No exact formula is available for determining the optimum number of levels. Usually the number runs from 6 to 20, depending upon many factors, most important of which are the total number of jobs being classified, the range in compensation, and the variety of skills covered. Company policy has an important bearing on the subject. If, for example, the company believes in frequent promotions, then substantially more job grades are needed as contrasted with a company whose policies are predicated upon the need for frequent pay increases but only occasional upgradings.

This job-evaluation technique is not too commonly used in industry. It is, however, almost universally applied in Federal, state, and municipal systems. The United States Civil Service system uses two basic classifications. The general schedule (GS) includes 18 levels, while the crafts, protective, and custodial (CPC) system contains 10 levels. In addition, many other institutions, specifically in the fields of education, finance, insurance, and hospitalization, use this technique.

TECHNIQUE 2. Quantitative Methods

Factor Comparison. As indicated in the title of this job-evaluation device, the various jobs are compared on the basis of a number of carefully selected factors. These factors are assumed to be common in all or in the vast majority of the jobs studied. In addition, the factors should be easily identifiable, distinct, and requisite to the effective performance of organization functions. The number of factors to be used can vary from 2 to 20 or more. Obviously, too few factors reduce this technique to the level of ranking. Using too many factors inevitably results in a cumbersome and ineffective tool. The most commonly employed versions of factor comparison contain five factors: (1) mental requirements, (2) skill, (3) physical requirements, (4) responsibilities, and (5) working conditions.

After agreement has been reached as to the requisite factors, key jobs must be selected. These key jobs, preferably numbering between 10 and 25, constitute a stratified sample. They should represent the entire job range, with a meaningful distribution over the entire range. There must be adequate variability so that no one skill or category of work predominates in the sample. All parties concerned must accept these key jobs as being representative. Most important, there must be complete agreement that the current pay of these jobs is equitable.

After satisfactory key jobs have been chosen, each job is analyzed in terms of the important factors. The jobs are then ranked on each factor. Up to this point the factor-comparison method resembles both ranking and classification except that job elements are considered rather than the job in its entirety.

Quantification of factor differentials is a significant advancement of this technique over the nonquantitative methods. This quantification is accomplished by assuming that the current pay rate is equitable. Dividing this pay rate among the factors is the next step. As shown in Exhibit 17-1, this apportioning of pay rates among factors yields situa-

Exhibit 17-1. Hypothetical Allocation of Key-job Wages, among Job-evaluation Factors

Key job	Wage	Requirements				
		Mental	Skill	Physical	Responsibilities	Working conditions
Assembler	2.75	45	70	60	60	40
Gear cutter	2.85	85	60	30	90	20
Hookup splicer	2.52	30	55	70	40	57
Laborer	2.01	10	15	86	70	20
Machine helper	2.23	25	40	65	45	48
Machinist	2.95	65	90	30	80	30
Shot-blast operator	2.36	30	65	55	50	36
Slotter	2.61	40	60	50	50	61
Truck driver	2.37	30	35	85	35	52

tions where some factors are allocated too many or too few points. The conclusion is obvious. Despite initial agreement as to the fairness of the compensation for that job, a more intensive study has shown that the difficulty and pay are, in such cases, not in equilibrium. The logical step is to eliminate such doubtful jobs from the key-job category.

The remaining key jobs constitute the framework around which the entire job structure can be built. When deemed necessary, additional secondary key jobs can be inserted to give a more complete framework. Finally, all the jobs are compared in terms of the basic factors with the rankings of the key-job factors. Repetition of the quantification process, as previously described, follows. Where after adequate comparison it is discovered that the job difficulty is in excess of the job pay, measures should be taken to correct the inequity. Where the pay is in excess of the job worth, a less direct course of correction must be

followed. An abrupt downgrading in pay can lead to dissatisfaction and to grievances. The procedure to follow in cases of overpaid jobs will be described later.

This brief analysis of the factor-comparison method presents only the essentials of this job-evaluation device. It has certain obvious advantages over the two techniques previously described. Stress on factor analysis and on quantification gives this method considerably more respectability as a scientific-management tool. In addition, use of the key jobs necessitates a tailor making of the technique to every instance of application. Although this results in higher costs, it purportedly means that the plan fits company needs more precisely.

From the opposite point of view there are numerous objections to rating jobs by factor comparison. The stress upon the monetary base for comparing factors can inject a *status quo* bias. It is all too easy for any group of raters to accept the current wage structure as being equitable. Then too, all jobs, including the key jobs, are necessarily fluid; hence the key jobs do not provide stable yardsticks. The tailor making, mentioned as an advantage of this method, can also become a serious limitation since it complicates comparison of a given concern's rate structure with those of other companies. This reduces the exactness, the assurance, the universality, and the utility of the method. Its claims to being an adjunct of scientific management would, consequently, be drastically reduced.

Point Systems. There are a number of related job-evaluation methods which can readily be placed into a single category termed point systems. In the industrial sphere this is the most widely used job-evaluation technique. Its proponents claim that this device more closely approximates a scientific methodology than do any of the other techniques. This claim seems to be substantiated by the greater stress it places upon constants, particularly in the allocation of points to job elements. The stress upon precisely set quantities and the insistence upon rigid definition make the method more stable, more readily comprehended, and probably more scientific.

All the variants of this category have certain common features. As in the factor-comparison method, the important factors or job elements must be segregated and defined. Agreement must be reached by all concerned as to what elements are to be used in the valuation. Once again the number can vary widely. One of the best-known point-system plans, developed by the National Metal Trades Association, includes 11 factors grouped under 4 basic topics: skill, effort, responsibility, and job conditions. Regardless of the number of factors, each must be carefully defined.

The next step in the sequence consists in dividing a factor into degrees. This division is based upon the extent or the intensity to which a specific job requires a given factor. There is no limit to the number of degrees that can be used although the NMTA's use of five degrees seems to be rather universally accepted. After deciding upon the number of degrees, each must be defined. This stress on objectivity adds much to the value of the method.

Selection and definition of factor degrees are followed by quantification. In the factor-comparison method, each job is assigned a number

Exhibit 17-2. Allocation of Points by Factors and Degrees

Factors	Degrees				
	1st	2d	3d	4th	5th
Skill:					
Education	14	28	42	56	70
Experience	22	44	66	88	110
Initiative and ingenuity	14	28	42	56	70
Effort:					
Physical demand	10	20	30	40	50
Mental and/or visual demand	5	10	15	20	25
Responsibility for:					
Equipment or process	5	10	15	20	25
Material or product	5	10	15	20	25
Safety of others	5	10	15	20	25
Work of others	5	10	15	20	25
Job conditions:					
Working conditions	10	20	30	40	50
Hazards	5	10	15	20	25

SOURCE: National Metal Trades Association.

of points varying with the cents paid on an hourly basis to the individual jobs. The factor-comparison technique thus uses a relative quantification. In the point systems, on the other hand, an agreed-upon maximum is allocated to each factor. Thus, for example, in the NMTA plan, a total of 500 points is allocated among the 11 factors. This allocation is shown in Exhibit 17-2. It is obvious that there is considerable disparity in the total points ascribed various factors and in the distribution of these points by degrees. Thus the three factors under the topic *skill* receive 250 points, half of the total attainable.

By contrast, the two components of the topic *job conditions* have only a combined worth of 75 points. Similarly, the 25-point allocation for the maximum degree of six of the factors is only slightly in excess of the 22 points ascribed to the first degree of the experience factor. An arithmetic progression of points assigned degrees is usually followed. However, a geometric progression, or even a less symmetrical distribution, might be used when deemed feasible. The important feature to note is the standardized and relatively rigid characteristic of this quantification. It relies upon absolute norms rather than upon relative or even arbitrary measures.

Mention of the NMTA's 500-point system should not be construed as meaning that this is the ideal plan. There is no optimum number of points, nor any perfect system for allocation. Obviously, too few or too many points impede effective evaluation.

Despite its stress on absolute standards, the point systems can incorporate considerable variability. This is attested to by the many versions of this system, which, incidentally, necessitate treating point systems as a category rather than as any single plan. For example, one of the General Electric Company's plans has even injected a 400-point base upon which the point system was superimposed. In this instance every job was assumed to have an initial value of 400 points plus the points ascribed for fulfillment of specified factor-degree requirements. A great many comparable innovations have been introduced in other leading American industrial organizations within the past twenty years.

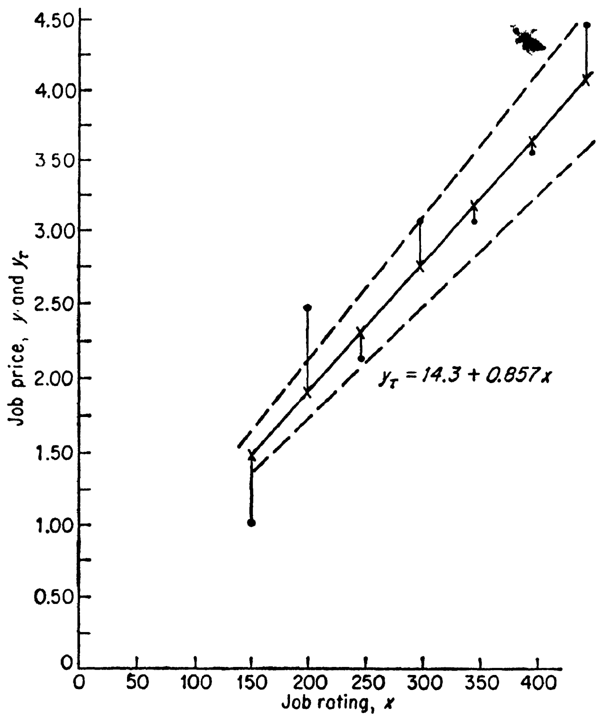
The quantification process demands that after each job is analyzed in terms of factors and degrees the point worth of each job be computed by simple addition. Once summations have been determined, comparisons among jobs become more meaningful. The relative job difficulty is evident from a simple inspection of point totals attributed to each job.

As was previously emphasized, the prime purpose of job evaluation is to ascertain a systematic progression of jobs on the basis of their importance to the organization. This point progression should then be converted into monetary units by use of a conversion factor. The simplest example would postulate that each point equals 1 cent. For example, a 260-point job would be assigned a base rate of $2.60. Obviously, in an inflationary period such a simple translation is complicated by every wage increase. Conversion factors, increasing with each wage rise, can readily be employed. Thus a 10 per cent wage hike would mean a conversion factor of 1.10. Multiplying the 260-point value by 1.10 yields a monetary value of $2.86—the new job price.

TECHNIQUE 3. Graphic Presentation—Arithmetic Progression

Graphic presentation is almost always used in the valuation process to show the logical relationship between job difficulty and job price. A simple two-dimensional portrayal uses the vertical scale to measure value and the horizontal scale to indicate variance in job difficulty. Simple inspection of the scatter diagram indicates that there is a correlation between the two variables. This correlation can be measured

Exhibit 17-3. Job–Price-rating Correlation



by a variety of means. The linear relationship can, for example, be indicated by a free-hand straight-line drawing. This free-hand drawing, while it approximates scientific methodology, is at best a measure of expediency to be resorted to with caution. Such estimates are useful where speed is imperative or where lengthier statistical techniques become prohibitively costly.

The recommended procedure to determine job-difficulty-valuation relationships is to compute a regression line. The easiest method, as set forth in Exhibit 17-3, is to consider the x axis, or the abscissa, as

the independent variable measuring job difficulty. The y axis, or the ordinate, represents the dependent variable, in this case monetary worth of the jobs. A straight-line relationship can readily be computed by using the straight-line formula, $y = a + bx$. In this process, the normal equations $\Sigma y = na + b\Sigma x$ and $\Sigma xy = a\Sigma x + b\Sigma x^2$ must also be used.

The following example is intentionally simplified so that a minimum acquaintance with algebra will suffice for computational purposes. Seven jobs, designated by the letters A to G, constitute the sample analyzed in Exhibit 17-4. While there might be some objections

Exhibit 17-4

Job	Job rating x	Job price y	xy	x^2	Computed job price y_T	Deviation $y - y_T$
A	150	100	15,000	22,500	143	−43
B	200	250	50,000	40,000	186	+64
C	250	200	50,000	62,500	229	−29
D	300	300	90,000	90,000	271	+29
E	350	300	105,000	122,500	314	−14
F	400	350	140,000	160,000	357	− 7
G	450	400	180,000	202,500	400	0
Σ	2,100	1,900	630,000	700,000		

that statistical inference should not be made from so small a sample, statistical accuracy is sacrificed in this instance for expediency, in order to give a more comprehensible illustration of the procedure. Each job has a point rating (column x) allocated by the job-evaluation committee after it has applied the rating sequence outlined in the preceding paragraphs. These point ratings, together with the job prices set forth in column y, have intentionally been set to facilitate the requisite computations. The job-difficulty point ratings in the x column represent the independent variable which, in the subsequent graphic presentation, is measured on the horizontal scale, termed the abscissa. The wage rate currently prevailing for the jobs constitutes the dependent variable. Presumably, job importance, as indicated by the rating, should determine commensurate wage rates. These value units in graphic presentation are generally measured on the vertical scale, that is, the ordinate.

The terms in the straight-line formula ($y = a + bx$) and in the two

normal equations ($\Sigma y = na + b\Sigma x$ and $\Sigma xy = a\Sigma x + b\Sigma x^2$) which are essential to the computations are:

x = job difficulty or rating, in points
y = present value of the job, in cents
y_T = equitable value of the job, in cents, as computed by the formula
Σ = term-indication summation
x^2 = job-difficulty points squared
xy = product of job points times job value
a = slope of the line (altitude divided by base)
b = intercept of the line
n = number of jobs in the sample

It is evident from Exhibit 17-4 that despite some of the figures running to six digits, the basic computations involve nothing more than simple arithmetic. For example, the jobs A to G number seven; thus $n = 7$. The x value equals 2,100, and the y value equals 1,900. Values of 630,000 for xy and 700,000 for x^2 are arrived at by simple multiplication and addition.

The next step involves substitution of the values computed in Exhibit 17-4 into the two normal equations:

Equation I	Equation II
1. $\Sigma y = na + b\Sigma x$	1. $\Sigma xy = a\Sigma x + b\Sigma x^2$
2. $1{,}900 = 7a + 2{,}100b$	2. $630{,}000 = 2{,}100a + 700{,}000b$

It is obvious that even after these preliminary calculations, two unknowns, a and b, appear in both the equations. Simple multiplication of line 2, equation I, by 300 would enable completion of the process:

$$300(1{,}900 = 7a + 2{,}100b)$$
$$570{,}000 = 2{,}100a + 630{,}000b$$

If this is subtracted from line 2, equation II, then:

$$\begin{array}{rcr} 630{,}000 & = & 2{,}100a + 700{,}000b \\ 570{,}000 & = & 2{,}100a + 630{,}000b \\ \hline 60{,}000 & = & 70{,}000b \end{array}$$

$$b = \tfrac{6}{7} = 0.857$$

Substituting the computed value of $b = 0.857$ in line 2, equation I, yields:

$$1{,}900 = 7a + 2{,}100b$$
$$1{,}900 = 7a + 1{,}800$$
$$7a = 100$$
$$a = 14.3$$

Thus the straight-line equation $y_r = a + bx$ becomes

$$y_r = 14.3 + 0.857x$$

From here on, it is merely necessary to substitute any known point value x ascribed to a specific job to determine what the pay rate for that job should be. Thus, if

$$x = 200$$

then

$$\begin{aligned} y_r &= 14.3 + 0.857(200) \\ &= 14.3 + 171.4 \\ &= 186 \text{ (approx.)} \end{aligned}$$

Similarly, if $x = 300$, then $y_r = 271$, and when $x = 400$, $y_r = 357$.

Plotting these or any comparable values yields the straight line as indicated in Exhibit 17-3. By this means it is possible, knowing the value of the independent variable, to compute the value of the associated dependent variable. It should be realized that in only very rare instances will every point fall exactly on the plotted line.

The technique which has just been described is an adaptation of one of the best-known statistical tools, the least-squares method. If y_r values are computed for each of the seven jobs, it is evident that there is a variance between the y values as shown in the y column of Exhibit 17-4 and in the y_r values derived from the computations. The least-squares method postulates that these deviations, if squared, will yield a sum lower than that which could be obtained from any other progression of computed y_r values.

The comparison between the given y values and the computed y_r values is shown in the last column of Exhibit 17-4. It is evident that the sum of the deviations above the line (64, 29) equals the sum of the deviations below the line (43, 29, 14, 7). More important, when these individual deviations are squared and the results are totaled, the sum, in this case 7,872, is the minimum figure obtainable. In the event that any other calculations for this particular example yielded a lower sum of deviations squared, then a new line would have to be drawn to fit the results of that calculation.

From the last column in Exhibit 17-4, conclusions can be drawn concerning the equity or inequity of specific job prices. Only job *G* seems to be paid exactly in proportion to job difficulty. Jobs *E* and *F* are nearly in line, jobs *C* and *D* somewhat out of balance, and jobs *A* and *B* are distinctly in need of adjustment. Corrective measures can be taken at this point if the straight-line wage structure is considered adequate for the organization's needs.

Rate Ranges. It is frequently deemed advisable at this point to establish rate ranges, thus permitting variance and a measure of flexi-

bility for each job. Rate ranges can readily be set by using the linear regression as the mid-point from which upper and lower limits are projected. These limits can be based on a prescribed percentage of each job price or as a set increment tacked on to every job price. The latter technique, obviously, gives the lower-paying jobs a relatively greater range. For example, a ±15 cent variance on a $1 per hour job is considerably greater than a similar range on, say, a $3-per-hour job.

Limits established on a percentage basis seem to have considerably more merit, particularly in cases where there is a great variety of skills in the jobs evaluated. The results of adding ±10 per cent to the linear progression in Exhibit 17-3 show only jobs *A* and *B* significantly outside the limits. Job *C* is only slightly out of line. If the job structure is to conform to the pattern, as shown in Exhibit 17-3, the underpriced jobs must, as soon as feasible, be brought up to the lower prescribed limits. Job *B* presents a far more perplexing situation.

Rate Adjusting. When overpriced jobs are encountered, they invariably are left alone on the supposition that immediate regearing would do more harm than good. It is assumed that downgrading would injure morale. Consequently, it is generally advisable to let time take care of the out-of-line job. The present pay is set as the ceiling for current occupants of that job. As attrition occurs, if replacements are made, they are given new and lower rates or new job titles with revised job descriptions and new job rates. While the hesitation to downgrade the overpaid jobs might be interpreted as a mark of managerial weakness, ignoring inequities though nonscientific, is frequently dictated by realism. In a great majority of situations where the workers are represented by a union, the union representatives are adamant in their refusal to downgrade as long as there are individuals filling the questionable positions.

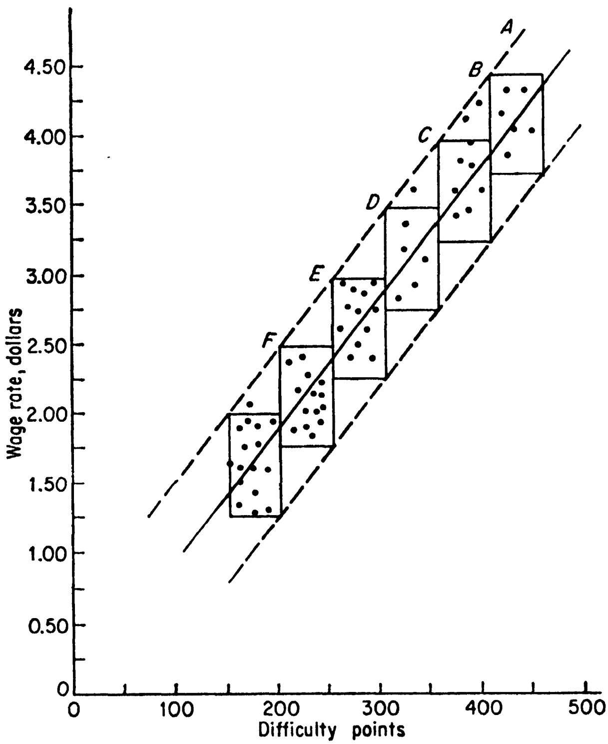
Job Grades. Another practical step associated with the establishment of a job structure is the grouping of all jobs with similar point ratings in job grades. Obviously, where the number of jobs is small, as in the previous seven-job example, grades are unnecessary. The use of grades, categories, or classifications becomes meaningful as the number of jobs increases.

There are a number of methods used in the grading process. The most practical device is shown in Exhibit 17-5. The rectangles in this case have distinct demarcations as to difficulty points but have a 25 per cent overlap as to job price. It is frequently imperative to provide for such overlapping of the wage rates to permit a more orderly progression. When the grading procedure is used, all the jobs within the

prescribed difficulty point limits are given the same base rate. The range in job price, as shown by the altitude of the rectangle, indicates that variance is permissible for seniority, or merit, or both.

In Exhibit 17-5 the position of the scatter diagram circumscribed by the lowest rectangle includes 14 dots representing 14 different jobs. Each dot indicates its relative job difficulty, measured on the horizontal scale, and its current pay rate, measured on the vertical scale. After

Exhibit 17-5. Job Grading



the grading pattern has been established, any new person hired into any one of these 14 jobs, whose difficulty points range from 151 to 200, would be given the base rate for grade *F*, which is $1.25. Eventually, because of seniority or excellent performance, a person on a job within grade *F* could earn up to $2 per hour. Similarly, grade *A*, including jobs with ratings from 401 to 450, has a base rate of $3.75 and a ceiling of $4.50 per hour. While this structure has a very fine symmetry, resulting from the arithmetic progression in difficulty and in wage rates,

reality frequently necessitates disproportionately wider ranges in both variables for the more important jobs. Thus, for example, job *A* might include jobs with point ratings from 401 to 475, while the wage rate might vary between $3.75 and $5.25. In such situations the lower classifications would be proportionately compressed. Grade *F* might then include only jobs with ratings between 151 and 175, with pay ranging from $1.25 to $1.50.

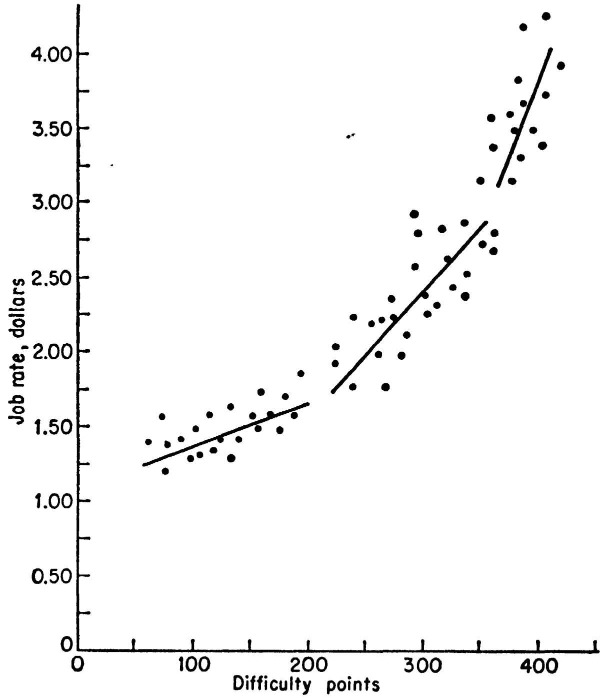
TECHNIQUE 4. Graphic Presentation—Geometric Progression

A modification resulting from the procedure outlined in the preceding section is the substitution of a curve in place of the straight line to indicate job relationship. The curvilinear method is especially useful where there is a very wide range of jobs and, particularly, when highly technical jobs are considered together with jobs requiring little or no special skills. In our highly complex economy it can be assumed that the highly technical jobs and those encompassing special administrative activities should receive disproportionately greater rewards than those associated with lower-level activities. This is particularly true when such factors as the negative force of progressive income taxation is considered. Besides the handicap of short supply of qualified technicians, managers, and administrators, there are all too many obstacles to attracting these strategically important individuals into industrial positions. Consequently, a geometric progression in job prices can have considerable merit as an incentive. The chief limitation in the use of these curvilinear schemes is their complexity. While geometric differentials between hierarchical levels in an organization are commonly used, it becomes rather difficult to translate these differentials into a systematic plan, scientifically computed and understood and accepted by the entire work force. Thus this stage of job evaluation should be restricted to concerns which have an adequate experience with the less complex phases. The development of a curvilinear graphic portrayal of a job-evaluation scheme is shown in Exhibit 17-6.

The three straight lines represent three separate job evaluations for three fundamentally different ranges of job complexity. While a single straight line could have been computed, it is obvious that fitting the jobs to such a line would have been most haphazard. Common sense dictates that with the data observed in the scatter diagram, unless extremely serious inequities are to be tolerated in the upper or lower job ranges, a curved-line fitting is distinctly preferable to a straight-line approach. While it is possible to use special formulas to set rigid prescriptions for calculating the curve, hand fitting, based

either on a series of straight lines, as shown in Exhibit 17-6, or on a judicious estimate, would generally be acceptable. This acceptance of hand-fitted geometric curves is merely a matter of expediency, considering complexity, costs, and utility. If these factors warrant, formulas, as previously stressed, are far more scientific and preferable. Once an acceptable curve has been drawn, all the preceding adaptations, such as limit lines and job grades, can be incorporated into a specific plan.

Exhibit 17-6. Development of a Wage Curve



Numerous other combinations and modifications of job-evaluation methodology are presently found in industry. A deeper analysis would necessitate an expansion of this chapter out of proportion to the importance of job evaluation in the over-all appraisal of managerial techniques. It is vital to remember that whatever scheme is used, the immediate objective is to attain an equitable alignment of all the organization's jobs and positions. This objective follows from the premise that equity in structuring and compensating all jobs is paramount for effective performance.

It seems superfluous to mention that once a job evaluation has been

installed, preferably on a custom-built basis, periodic reappraisal is absolutely essential. The follow-up process is integral, not only for effective job evaluation, but for the optimum utilization of any of the industrial-management techniques.

Closely associated with adequate follow-up is the willingness of all participants to accept demonstrated changes. Adherence to outmoded jobs inevitably leads to featherbedding and similar unjustifiable obstacles to sound organization. If a particular organization prefers to vegetate in its apathy, the probability is extremely high that in a dynamic economy such an organization must inevitably retrogress even to ultimate dissolution.

ILLUSTRATION 1. Job Evaluation and Wage Theory

A recent study by 12 leading labor economists focuses attention on the importance of precise job evaluation for a better comprehension of our over-all wage theory and for more effective industrial management. The 12 labor economists met over a three-year period at the Wharton School's Labor Relations Council to explore new approaches to the subject of wage theory. The product of their joint endeavor was published in 1957.[2] The group resurrected, for analysis, but then rejected, some long-interred theories, such as the wages-fund concept, which postulated that wage rates were simply determined by dividing the supply of labor into the sum of capital available for wages. As every student who has had a course in economic principles knows, this premise, closely associated with the rejected subsistence theories, has long been disproved.

Another well-known and long-accepted notion, the marginal-productivity theory of wages, is also presumed inadequate by the 12 labor economists. Their dissatisfaction is based upon weaknesses in the marginal-productivity theory which have been debated for several score years.

The contribution of the Wharton group to industrial management is the proposed thesis that a wage structure is a tightly balanced system, built upon (1) a job cluster, (2) a wage curve, and (3) a wage contour.

A job cluster represents a stable group of jobs within a company or a component of a company. These jobs should be associated because of factors such as a common technology, custom, or administrative convenience. All the job rates in a specific job cluster are intimately related. Employees within the cluster quickly sense over- or underpayment in terms of the jobs within the cluster. Generally, there is one

[2] George W. Taylor and Frank C. Pierson, *New Concepts in Wage Determination*, McGraw-Hill Book Company, Inc., New York, 1957.

key job within each cluster which serves as the yardstick for that group. This key job can be either the highest-ranking job in the cluster or a job held by a very large portion of the workers within that job cluster.

A wage curve is the product of a number of related job clusters being linked together to form a progression covering a wide range of jobs. Preferably, the cluster key jobs should influence the pattern of the wage curve.

The third phase, *a wage contour,* combines the wage curves of a group of companies. A wage contour can be restricted to a specific geographic area. This sort of isolation tends to produce geographic differentials within industries or trades. On the other hand, and particularly in those industries characterized by industry-wide bargaining, a contour can encompass an entire basic sector of our national economy. The pattern of the contour is established in a manner similar to that by which the key job sets the level for a job cluster. The leading company or group of companies tends to set a precedent emulated by the "follower" companies.

This digest of the newest theory of wages highlights the value of a sound job-evaluation program. The wage contour for an entire industry, a segment of an industry, or a geographic area is only as stable as the composite of wage curves from which the wage contour is derived. In turn, the wage curve is absolutely dependent upon the job cluster. It is within this basic unit that the application of scientific methodology in determining equitable job relationships is paramount. Job evaluation offers a scientific means by which the key job or jobs within a cluster can readily be identified, measured, and evaluated.

QUESTIONS

1. Could this wage theory be assumed to have an empiric base?
2. Does this new approach completely reject marginal-productivity premises and conclusions?
3. If time and testing prove this theory to be sound, what form of job evaluation would you recommend as being best suited for the average manufacturing enterprise?
4. Can you note any serious limitations, in premises or conclusions, regarding this new theory of wages?

ILLUSTRATION 2. United States Employment Service Classification System

The United States Employment Service (USES) recently introduced a new device in the sphere of job classification. Exhibit 17-7, taken from *Business Week,* illustrates the basic principles of this innovation. The form shows the close relationship of three job classifications: machinist, shop carpenter, and wood turner. This similarity in profile presumably should enable an organization's hiring agent to make satis-

Exhibit 17-7. United States Employment Service New Job Classification System

	Machinist	Shop carpenter	Wood turner
Education:			
General education development	5	5	4
(level of ratings, lowest to highest, 1–7)			
Specific vocational training	7	7	7
(length of education, shortest to longest, 1–9)			
Aptitudes:			
(Scale of aptitudes, highest to lowest 1–5)			
Intelligence	3	3	3
Verbal	3	3	3
Numerical	3	3	3
Spatial	2	2	2
Form	2	2	3
Clerical	4	4	4
Motor coordination	3	3	3
Finger dexterity	3	3	3
Manual dexterity	2	3	2
Eye-hand-foot coordination	5	4	5
Color discrimination	5	3	5
Temperaments:			
Variety and change	•	•	
Repetitive, short cycle			
Under specific instructions			
Direction, control, planning			
Dealing with people			
Isolation			
Influencing people			
Performing under stress			
Sensory or judgmental criteria			
Measurable or verifiable criteria			•
Feelings, ideas, facts			
Set limits, tolerances, or standards	•	•	•
Interests:			
Things and objects			
Business contact			
Routine concrete			
Social welfare			
Prestige			
People, ideas			
Scientific, technical			

Exhibit 17-7. United States Employment Service New Job Classification System *(Continued)*

	Machinist	Shop carpenter	Wood turner
Interests:			
Abstract, creative			
Nonsocial	•	•	•
Tangible, productive satisfaction	•	•	•
Physical capacities:			
Strength (medium)	•	•	•
Climbing-balancing			
Stooping-kneeling		•	
Reaching-handling	•	•	•
Talking-hearing			
Seeing	•	•	•
Working conditions:			
Inside-outside: (inside)	•	•	•
Cold			
Heat			
Wet-humid			
Noise-vibration	•		
Hazards	•		
Fumes, odors, etc.		•	

SOURCE: *Business Week,* June 29, 1957, p. 144.

factory substitutions in cases where a particular skill is in short supply. In theory, the three jobs depicted in Exhibit 17-7 have so many traits in common that a minimum of retraining would be needed to move, for example, a shop carpenter into a machinist job.

The USES first large-scale venture in this experiment has broken down into subdivisions the education, aptitudes, temperaments, interests, physical capacities, and working conditions needed by each of 4,000 different jobs. These are the most common jobs out of the 23,500 listed in the *Dictionary of Occupational Titles.* For a long time the USES has recognized the plaguing problem of sporadic short supplies of specific skills. Grooming apprentices is, obviously, a long-term proposition. On the other hand, there frequently are oversupplies of labor in certain categories. This disequilibrium prompted the USES nearly twenty years ago to initiate a plan whereby labor resources could be more effectively utilized. In 1950 this Federal agency undertook the project which seven years later materialized in the current innovation.

Basically, the new technique simply seeks to find, from adequate job descriptions, the traits requisite to effective performance in given

types of work. Frequently jobs which by their titles seem to have no skills in common upon closer analysis turn out to be technically interchangeable. *Business Week* mentions the parallel jobs of bituminous-coal scoopman, construction flagman, and lobster fisherman. However, the traits needed by a lobster fisherman and a clam fisherman are not identical.

There seems to be considerable practical value to this determination of specific traits requisite to nationally standardized jobs. An individual's traits as determined by tests and by work records can readily be punched on a card system. Machine selection of these coded profiles can then be made according to a given set of job requirements. This method widens the range of potential available for most jobs. In contrast, the current practice of listing individuals as being qualified for one given job results in a very narrow and rigid enumeration in each job category.

The proponents of the new classification system claim that it will eliminate wasting of manpower frequently resulting from technological change. A better comprehension of trait requirements for specific jobs should also be of value for promotion-from-within situations. Deficiencies in workers can also be more objectively appraised. The stress on individual differences, say proponents of the plan, reduces compartmentalization which accompanies the present rigid delineation of job categories.

Opponents of the new plan raise some serious questions as to the reliability and validity of personality and placement testing. Despite much lauded praise of testing techniques, many individuals suspect that these devices are grossly overrated. Other sceptics see the proposed plan as a further encroachment upon the individual prerogatives. Once an individual is "typed," he will then be mechanically shunted to and fro according to the whims of a centralized planning agency. This, then, would be a further step in the direction of a "classified" society.

Regardless of pro and con views, the USES in mid-1957 introduced the profiling system into 1,700 of its offices. Since these offices fill an average of six million jobs a year, there is a high degree of assurance that within a few years the new technique will be adequately tested.

QUESTIONS

1. Is this technique a radical departure from prior methods?
2. Is this a move in the direction of regimentation?
3. Considering the traits and subtraits listed in Exhibit 17-7, how dependable do you think present testing techniques are for evaluating personalities and aptitudes?

4. What benefits will the individual receive from this innovation?
5. Could this new method properly be termed an attempt at job standardization?

ILLUSTRATION 3. Equitable Wage Payment

An office-equipment factory in Romford, England, recently experienced a strike because of a grievance arising out of the theory that what comes out of the plant must equal what goes into the plant. The employees in this instance walked out because they believed that two workers at opposite ends of a conveyor belt should get the same pay. At the one end of the conveyor belt a workman regulated the flow of raw materials into the belt for processing. At the opposite end another workman unloaded the finished product from the line. This handler of the finished product was being paid a higher rate than that given the worker at the head of the conveyor. In this case, management promised to study the facts relevant to the issue.

QUESTIONS

1. Under what circumstances might this work stoppage be justifiable?
2. Although the facts presented are rather meager, what seems to be the underlying grievance manifesting itself in this very questionable action?
3. What procedure could you recommend to management for its analysis of facts relevant to this grievance?

ILLUSTRATION 4. The E. W. Bliss Company Job-evaluation Program

The job-evaluation procedure used at the Canton, Ohio, Division of the E. W. Bliss Company is based upon the *Cooperative Wage Study Manual for Classification of Production and Maintenance Jobs.* This procedure is provided for in the agreement between the company and Local 4396 of the United Steelworkers of America. In the contract both parties agree to the establishment of a standing committee on job evaluation, consisting of three member representatives from each party. It is the function of this committee to prepare, negotiate, and approve the pertinent job descriptions and classifications.

Exhibit 17-8 is a typical example of the job description used for all jobs being evaluated. Note the relatively brief statement in reference to the primary function of the job. This summary description facilitates comparison between jobs when there is a minimum need for detailed analysis. However, when detailed comparison is imperative, the interested parties can use the final section of the job description labeled "working procedure." In this lengthier explanation of job characteristics and responsibilities, the 10 or 12 major activities are each explained by a single phrase or brief sentence.

Exhibit 17-9 is the reverse side of the job-description form. Twelve factors, as listed, comprise the basis for the job classification. In each

Exhibit 17-8

Form P-22 Rev. 9-51

E. W. BLISS COMPANY
JOB DESCRIPTION

Department	MACHINE SHOP	Standard Code	
Sub Division		Standard Title	MACHINE OPERATOR
Plant	CANTON	Plant Title	MEDIUM PLANER
Date	8-30-51 (Retyped 11-15-54)	Plant Code	418

Primary Function: Set up and operate a medium planer.

TOOLS AND EQUIPMENT:

Equipment such as:
56" x 150" Gray
56" x 218" Sellers
44" x 240" Cincinnati
40" x 120" Liberty
32" x 240" Gray

Various types and sizes of micrometers, scales, dial indicators, levels, calipers, gages, templates, cutting tools, clamping devices, and miscellaneous hand tools.

MATERIALS USED:

Steel weldments, castings, forgings, plates, oil waste, etc.

SOURCE OF SUPERVISION:

Turn Foreman.

DIRECTION EXERCISED:

None

WORKING PROCEDURE:

Checks prints, operation records, sketches, and rough parts.
Plans proper sequence of work to be done; lays out job.
Makes set-up, clamping and adjusting as necessary.
Selects proper tooling and adjusts machine for proper productive speeds and feeds.
Operates machine to cut, straight, angle, bevel and contours on a wide variety of parts, for presses and other equipment, of various metals and alloys, machining to a close tolerance.
Adjusts operation of machine as necessary and checks work in process for tolerance.
Lubricates and greases machine as required.
Assists Crane Operator by hooking and unhooking material, loading and unloading machine or assists Hook-up man on such work.
Checks to insure proper operation and lubrication of equipment.
Maintains order and cleanliness of machine, tools and equipment.

The above statement reflects the general details considered necessary to describe the principal functions of the job identified, and shall not be construed as a detailed description of all of the work requirements that may be inherent in the job.

instance a brief statement is needed to indicate the approximate extent to which the particular job fits the factor. On the right-hand portion of this sheet are two columns; the first identifies the factor degree by an alphabetical coding, the second converts the code and the factor degree into an appropriate numerical value. A summation of the 12 factor values, as shown in the extreme right-hand column,

Exhibit 17-9

JOB CLASSIFICATION

Plant Title MACHINE OPERATOR Standard Title

Factor / Reason For Classification	Code	[illegible]
1. Pre - Employment Training. This Job Requires The Mentality To Learn To: Interpret detailed part drawings.	C	1.0
2 Employment Training And Experience. This Job Requires Experience On This And Related Work Of: Nineteen (19) to twenty-four (24) months.	E	1.6
3. Mental Skill: Reason through set up problems and use considerable judgment in operating equipment.	D	2.2
4. Manual Skill: Use a number of machinist hand tools on a wide variety of tasks involving close tolerances.	D	1.5
5. Responsibility For Material (Estimated Cost): Use very close attention to prevent damage to parts. $250.00	E	2.3
6. Responsibility For Tools And Equipment: Moderate care and attention required to prevent damage to machines and cutting tools.	MD C	.7
7. Responsibility For Operations: Individual processing unit requiring some coordination with others.	C	1.0
8. Responsibility For Safety Of Others: Ordinary care to prevent injury to others occasionally exposed. Occasional crane hooking.	B	.4
9. Mental Effort: Close mental and visual application required in checking progress of work, resetting for recuts, etc.	D	1.5
10. Physical Effort: Light physical exertion in manipulating machine tool controls.	B	.3
11. Surroundings: Normal machine shop conditions	A	---
12 Hazard: Accident hazard moderate. Exposed to hazard of moving machinery--severe cuts, bruises or fractures.	B	.4

Job Class 13 Total 12.9

Described By: W.D.S. Date 11/5/51 Retyped 3/7/58

Classified By W.D.S.

Approved By:

yields the point value or classification for the job. Rounding this value to the nearest discrete figure serves as the basis for allocation to job classes. In this instance the job of engine lathe machine operator, with a point value of 12.9, is placed in job class 13.

It should be noted that the numerical values are not based on any exact arithmetic or geometric progression. While this gives much more

Exhibit 17-10

MENTAL SKILL—3

Consider the Mental Ability, Job Knowledge, Judgment, and Ingenuity required to visualize, reason through, and plan the details of a job without recourse to supervision.

Code	Job requires ability to:	Benchmark jobs	Numerical classification
A	Perform simple, repetitive routine tasks. Do simple sorting. Make changes in routine only when closely directed.	Laborer Stocker o. h. Wharfman—c. p. Scrapman—bil. shr.	Base
B	Make minor changes in routine or sequence on repetitive jobs involving selection, positioning, and recognition of obvious defects or adjustments where tolerances are liberal.	Charger bar mill Wire bundler Pipe stenciler	1.0
C	Perform semiroutine job involving some variety of detail and requiring judgment. Sort material according to size, weight, or appearance.	Chipper—cond. Bottom maker s. p. Stitcher oper. Assorter—tin plate Tractor operator—ram Craneman—h. s.	1.6
D	Reason through problems involving setup and operation of moderately complex equipment. Use considerable judgment in operating equipment. Exercise considerable judgment in selecting and using materials, tools, and equipment in construction, erection, or maintenance work.	Slitter operator Finisher—h. s. Charging mach. oper. o. h. Ore bridge oper. Carpenter A Bricklayer A Millwright—b. m.	2.2
E	Plan and direct the operation of a large complex production unit. Reason through and plan operating problems. Plan work detail from complex blueprints.	Tandem mill roller 1st helper—o. h. Machinist A Boilermaker A	2.8
F	Analyze and plan complex nonrepetitive tasks to be performed by skilled workmen.	Layout man A (development work)	3.5

flexibility in the weighting process, it can also be the source of controversy as to the reasons for lack of symmetry in weighting factor degrees. Exhibit 17-10 shows the detailed analysis of the third factor, "mental skill." The factor has six subdivisions, each coded in terms of a letter of the alphabet. The job-requirement column gives the basic reasons for the differentiation as to degrees of difficulty. The "benchmark job" column provides an easy means for comparison purposes since presumably these benchmark jobs are fairly well known by all concerned. The "numerical classification" column shows the results of quantification. In this instance code *A* receives no point value, while code *F* is designated as being worth 3.5 points. The intermediate subdivisions are ascribed proportionate numerical weights. In the hypothetically most difficult job situation, the maximum value for the 12 factors would be as follows:

	Points
1. Preemployment training	1.0
2. Employment training and experience	4.0
3. Mental skill	3.5
4. Manual skill	2.0
5. Responsibility for materials	10.0
6. Responsibility for equipment	4.0
7. Responsibility for operations	6.5
8. Responsibility for safety of others	2.0
9. Mental effort	2.5
10. Physical effort	2.5
11. Surroundings	3.0
12. Hazards	2.0

It should be emphasized that although 43 is the maximum number of points that can be allocated to a single job, this ceiling cannot be reached in actual practice. The inherent characteristics of most jobs tend to pull the job in one difficulty direction but at the same time away from other maximum degrees of difficulty.

The technique for comparison of factors has already been discussed in previous sections. In this instance, the following is the distribution of the 151 jobs rated at the Bliss Company in respect to the "mental skill" factor and its six coded categories: $A = 8$, $B = 29$, $C = 41$, $D = 42$, $E = 27$, $F = 4$.

After all jobs have been compared as to factors and degrees of difficulty, a summary is ventured in the job-classification analysis. In the interests of clarity, the illustration in Exhibit 17-11 shows only six jobs. Obviously, the more accurate analysis would require a complete summary of all jobs involved. This particular example also lists the jobs in descending order of over-all difficulty. Thus inspection of the list

Exhibit 17-11

E.W.B.Co. Form C-30

JOB CLASSIFICATION ANALYSIS

DISTRICT OR DIVISION__________ DATE__________ DEPARTMENT__________

PLANT__________ SUB-DEPARTMENT__________

JOB TITLE	PRE-EMPLOYMENT TRAINING	EMPLOYMENT TRAINING AND EXPERIENCE	MENTAL SKILL	MANUAL SKILL	RESPONSIBILITY FOR						EFFORT		SURROUNDINGS	HAZARD	TOTAL CLASSIFICATION	JOB CLASS	REMARKS
					MATERIALS		EQUIPMENT		OPERATIONS	SAFETY OF OTHERS	MENTAL	PHYSICAL					
					CODE	CLASS	CODE	CLASS									
	1	2	3	4		5		6	7	8	9	10	11	12			
Machinist	C	H	E	D	E		MD C		C	B	D	D	A	B			
	1.0	3.2	2.8	1.5		3.2		0.7	1.0	0.4	1.5	0.3		0.4	16.0	16	
Building Maintenance Man	C	H	D	D	D		LO C		C	B	C	C	B	C			
	1.0	3.2	2.2	1.5		1.1		0.4	1.0	0.4	1.0	0.8	0.4	0.8	13.8	14	
Machine Operator -	C	E	D	D	E		MD C		C	B	D	B	A	B			
Md. Planer	1.0	1.6	2.2	1.5		2.3		0.7	1.0	0.4	1.5	0.3		0.4	12.9	13	
Machine Operator -	C	E	D	D	E		MD C		C	B	D	B	A	B			
Eng. Lathe	1.0	1.6	2.2	1.5		2.3		0.7	1.0	0.4	1.5	0.3		0.4	12.9	13	
Machine Helper	A	B	A	B	B		LO B		A	B	B	C	A	B			
		0.4		1.6		0.5		0.2		0.4	0.5	0.8		0.4	5.1	5	
Laborer	A	A	A	A	A		A		A	B	A	C	B	B			
										0.4		0.8	0.4	0.4	2.0	2	

should suffice to convince that the job of machinist is significantly more difficult and worth more pay than is the laborer's classification. Quantification as to differences in degree of difficulty should lead to quantification in terms of monetary worth. The procedure as used at E. W. Bliss Company as of September 1, 1958, begins with a base rate of $1.96 for the combined job classes 1 and 2. Thereafter each job class has an increment of $0.067 over the preceding class. The top base pay under the standard hourly wage scale reaches $3.032 for job class 18, the highest rating possible under the present structure.

QUESTIONS

1. In what respects does the E. W. Bliss Cooperative Wage Study plan resemble each of the four basic job-evaluation techniques?

2. What are the base pays under the current agreement for the six jobs listed on the job-classification-analysis sheet?

3. Comment on the wage pattern in effect at the E. W. Bliss Company's Canton Division.

4. The 162 job titles covered by the most recent agreement with the United Steelworkers of America are distributed among the job classes as follows: 4, 3, 1, 17, 15, 7, 10, 16, 7, 14, 11, 11, 25, 9, 10, 0, 2. Job classes 1 and 2 are combined, and the others follow in sequence. What inferences, if any, can you draw from this distribution?

CHAPTER 18

Wage-incentive Systems

DEFINITION AND DESCRIPTION

The importance of job evaluation for wage-payment purposes has been stressed in the previous chapter. If science and equity are employed in ranking jobs and in attaching monetary values to these jobs, then the entire wage pattern is given a symmetry and cohesiveness most conducive to industrial dynamism. However, job evaluation is only one important aspect of wage theory and practice. Not only is it important to determine a job's relative rank and basic worth, but it is equally important to inject into the wage-payment system an additional vitalizing force by means of wage incentives.

While job evaluation establishes a wage-payment system with compensation proportionate to job difficulty, it does not provide for variance in performance among individuals on the same job. The function of incentive systems is to stimulate individuals on given jobs not only to meet prescribed quotas but even to exceed these accepted norms. Wage incentives, then, simply provide extra pay for extra performance. In practically every instance the incentive plan guarantees a minimum wage—this minimum can be set by law or custom, by economic conditions, or by collective bargaining. The methods for calculating extra performance vary considerably, so much so that in the following sections only a few of the more representative plans can be studied.

While there is considerable diversity among wage-incentive plans, they all have several features in common including:

1. Acceptance of the concept of productivity as described in Part One
2. Belief in the inevitability of inequality as to ability and diligence in performance
3. A firm conviction that compensation should be strictly proportionate to contribution

Wage-incentive systems are a radical departure from utopian and equalitarian dogmas. The medieval "just price," for example, set a standard wage presumed to be fair for all services of a particular category. The religious spirit motivating the "just-price" concept was postulated upon the premise that a fair degree of economic and political equality existed among the workers. A similar quasi-religious spirit still prompts certain groups, and particularly some segments of the trade-union movement, to place undue emphasis upon equally inflexible wage structures. These same trade unionists invariably set specific job-content quotas not to be exceeded by their members.

All modern wage-incentive theories assume that every worker should be paid at least enough to meet his prime needs. It is for this reason that every incentive plan begins with a guaranteed base rate. Beyond this common base, however, differences in individual payments must inevitably appear. The reasons for such variance are associated with individual differences in ability and productivity. Our economic system is based upon the concept that rewards should be commensurate with individual contribution. Thus *deed* is the fundamental criterion for wage payment. This differentiates our income-distribution system from those utopian ideologies based upon *need.* "To each according to his needs" is the hackneyed aphorism expressing the income-distribution philosophy of various do-gooders. Two other philosophies of income distribution should also be included in this mnemonic. Income distribution according to *breed,* while shrugged off as being aristocratic and un-American, is nevertheless still prevalent in some segments of our economy. The fourth system, based upon *greed,* is evidenced by opportunistic, acquisitive, law-of-the-jungle scrambles for money and power.

It should be obvious that all four fundamental theories of income distribution are found within our American society. Greed, sometimes falsely masquerading as legitimate free enterprise, is still condoned despite a growing body of restrictive laws such as those enforcing progressive income taxation and excess-profits taxes. Breed is still tolerated as a rightful income-distribution device. Nepotism in industry, perpetuation of family fortunes to the *n*th generation despite supposedly severe inheritance taxes, and similar evidence bear out

the existence of what might very easily be termed an American aristocracy. Need is generally accepted as a legitimate reason for setting minimum incomes adequate to meet a twentieth-century subsistence level.

Fortunately, the great mass of our citizenry subscribes to the concept that rewards should be proportionate to individual contributions. While this necessarily means an inequality in income distribution, it does provide a sound basis for a dynamic society. This dynamism originates in psychological impulses or traits variously described in terms such as the economic-man concept and the principle of self-centered appreciation, or self-interest. Irrespective of origin, the evidence is irrefutable that the world's first wide-scale experiment in rewarding extra effort and extra ability by proportionate income increments has demonstrated its merits.

This brief discussion of wage theory, while it verges on philosophizing, is a necessary groundwork for the more complete comprehension of scientifically devised wage-incentive systems. Rudimentary forms of day rates and piece rates have been used for many hundreds of years. The plans discussed in this chapter differ from the pristine versions in the method by which the wage structure is devised and in the norms used in calculating extra payment for extra contribution. Before venturing into an analysis of specific plans it seems imperative to review a few of the tacitly accepted yet infrequently expressed attributes of labor.

Manpower is characterized by:

1. Rapid deterioration or perishability
2. A "psyche," which means that the labor factor is not entirely biological or strictly a commodity
3. Adaptability to environmental forces
4. Independence
5. A tendency toward inertia
6. Individual differences

The perishability characteristic implies that manpower unused for a period of time can hardly be stored for future use. Thus it is imperative to maximize the use of labor when such labor is at its best and is available for use.

The extrabiological aspects are sometimes viewed from extremes. At present the commodity version of labor has very few adherents in this country. However, there seems to be adequate evidence that in some parts of the world, in the purchase and use of labor, there is frequently only a token demarcation between manpower and animal power. On the other extremity, there are still occasional misguided

individuals who inadvertently seek to deify the worker. Elevating the labor factor upon a lofty pedestal and refusing to admit any limitations in the labor factor is distinctly partisan fanaticism.

The continued survival of the human race is conditioned by its ability to adapt to changing environment. Consequently, it seems logical to assume that the labor factor will, at least temporarily, adjust to whatever external forces prevail. However, in the long run a favorable working climate should be expected to be more conducive to superior performance.

The characteristic of independence of manpower scarcely needs comment. Even in slave economies, legal possession never meant complete control of body, and much less of mind. The less-than-optimum utilization of manpower in areas where freedom is seriously abridged is ample testimony of this characteristic's importance.

The inertia trait means that manpower tends to become relatively static unless prodded by internal and external forces. Generally these impulses are psychological and economic in origin. Pride, fear, acquisitiveness, lust for power, and similar urges can, and do, induce greater expenditure of effort and more intense dedication to attainment of objectives. Decrease in these forces conversely leads to apathy and retrogression.

Finally, the topic of individual differences forcibly points out that there is no possibility of absolute standardization of manpower. While a standard might be set as the minimum expectation for a specific job, this does not mean that the standardized job is performed by standardized workers. For one man such a job might demand supreme effort and a maximum of time allowed. Another individual might expend only a bare fraction of his potential and of the time allocated to complete the same tasks. The hereditary and environmental causes for these individual differences leading to the inevitability of inequality in the work place cannot be analyzed in this text. Their effect is amply seen in the realities of life.

These comments on several important aspects of labor have been ventured on the premise that better comprehension of these aspects will be conducive to better understanding of wage-incentive systems. Even these brief comments should suffice to highlight the extreme difficulty in devising a method whereby every member of an organization will be motivated to perform at his maximum capacity. The problem is further complicated by a host of additional variables, too numerous to mention, which affect in an almost infinite variety the productivity of individuals. What is stimulating for one person can be demoralizing for another. Consequently, in the interests of clarity

and cohesion, it is expedient to consider at this time only that incentive which seems to have the most universal motivation, namely, monetary compensation. The importance of nonmonetary incentives has already been discussed in earlier chapters.

An incentive system which would seek to induce "a thousand donkeys" to perform prodigious tasks by dangling only a single carrot before them would, obviously, be ineffective. It is extremely important that any incentive plan should provide an adequate number of "carrots" to a large number of the carrot-motivated creatures. Otherwise the incentive plan will have only an incidental motivating power. It is this realization which gives logic to the "produce-more, share-more" philosophy which characterizes our system.

The inception of scientifically designed wage-incentive plans, slightly more than a half century ago, has been described in Frederick Taylor's classic experiments in Chapter 2. The pros and cons of this Taylor innovation have been inferred in the earlier analysis. Specifically, the charge that pay increments never match the requisite expenditure of extra effort and ability continues to reappear periodically. To forestall such baseless allegations, it must be clearly understood that the labor factor is simply one ingredient in the industrial process. To funnel all extra benefits to this single factor would be an admission that this factor alone was responsible for the increased productivity. Basically, then, all wage-incentive systems agree that only a portion of the production increment is to be apportioned among the work force. The various wage systems differ in regard to the portion of the production increment to be allotted to the labor factor, the method of allocation, the portion accruing to each person or job, the relative size of extra payments, etc.

The symmetry to be followed in describing several of the more important wage-incentive techniques should call attention to the interplay of several constant and variable factors. To most production-orientated minds *time* is the most important constant. While it is obvious that the time required to complete a specific task can vary considerably, the work time spent by an individual on the job tends to remain constant. The great variable is *productivity*—the rate of output per unit of time. Every one of the following techniques, regardless of the claims set forth by the plan's proponents, is fundamentally merely a means of measuring variable output or productivity per constant unit of time.

The sequence of techniques presented in this chapter is based upon technical complexity. The progression from day-rate payment to piece-rate can be effected rather easily by the mere prescription of an "ex-

pected" output per hour or per day. For example, a $12-per-day job and a $0.10 piece rate are practically identical if the average output on the piece-rate system equals 15 per hour, or 120 units per 8-hour day.

The transition from piece rate to constant sharing and finally to the empiric plans is very logical. The development hinges, however, upon the degree to which:

1. Work standardization can be effected
2. Employees can control those variables pertinent to improved productivity
3. The plan has incentive pull

While there is a tendency among some writers on the subject to cast aside the names of the individuals who devised specific plans, for purposes of clarity and facility in comprehension this presentation will follow the conventional labeling. Thus, instead of terming a specific technique as "an incentive beginning at standard or 100 per cent productivity and with 100 per cent participation," this chapter will refer to such plans as straight piecework. The movement in nomenclature to disassociate the founder's name from the specific plan, while commendable in some respects, has serious limitations. All scientific-management tools become suspect in the employee's mind when such tools introduce complex calculations, involved formulas, or out-of-this-world titles. While it is absolutely impossible to present management techniques without at least a cursory reference to arithmetic devices, the older, founder-designated wage-incentive plans seem to rely less on complex manipulation than do the recent innovations. Facility in identification and in comprehension prompts this decision to retain the original nomenclature.

TECHNIQUE 1. Time-payment Plans

Measured Daywork. Strictly speaking, time-payment plans are seldom considered as belonging to the category of wage-incentive systems. There is no question as to their being accepted methods for payment of wages. Actually, the time basis is by far the oldest and probably even now the most commonly used norm for determining an employee's earnings. Disagreement arises, however, over the use of the term *incentive* in conjunction with time-payment plans. Most authorities conclude that the conventional time-payment plans do not make any provision for extra payments for special effort and hence should be excluded from the incentive category.

Despite what might appear to be a semantic distinction, measured daywork is, nevertheless, included in this summary analysis because of

the "measured" aspect. This feature injects a factor which so changes this type of time payment that it assumes many of the characteristics of a legitimate incentive technique. The plan uses hourly rates varying for all employees. These hourly rates are revised periodically, usually every three, four, or six months. The basis for revision is the effectiveness of an individual's performance as gauged by carefully set standards. Fundamentally, this feature simply adds a merit-rating factor to the procedure by which individual rates are determined. For proper use of this technique, it is very important to use scientific methodology in the setting of standards and in the application of merit rating. Otherwise the measured characteristic is actually lacking and the plan reverts to the ordinary, usually haphazardly set daywork.

Among the more serious objections to measured daywork is the inference that it is no improvement over the commonly used wage-range technique. Under a wage-range arrangement, there is a minimum pay guaranteed beginners and a maximum job rate attainable only through merit rating and seniority. In rebuttal to this charge, it should be emphasized that there is always the possibility of rates being revised downward under the measured-daywork plan when poor performance so warrants. Then too, the impact of seniority is either modified or nullified. Other limitations of this technique include the danger that too much stress on relative factors results in a gradual disintegration of absolute standards. The use of a quarter or half year as the interval for adjusting rates might also discourage some rapidly improving workers.

On the other hand, the advantages include the attainment of a common denominator in the time standard which facilitates comparison of performance effectiveness even for unlike jobs. The mechanics of the plan are simple. Calculations are easy to make and to comprehend. The merit-rating aspect necessitates closer supervision, resulting in the foremen getting a better understanding of their personnel. Modifications in operating methods can also generally be effected more easily since such improvements usually mean better performance and higher ratings.

Measured daywork has been included in this chapter to emphasize the possibility of easy transition from the orthodox time-payment basis to the far more scientific approach of adjusting rates to performance-quantity-quality-merit norms. Despite modifications in terminology and computational techniques, it should be noted that measured daywork and the subsequent wage-incentive-payment techniques have considerable similarity. Many of the so-called differences are merely a matter of semantics.

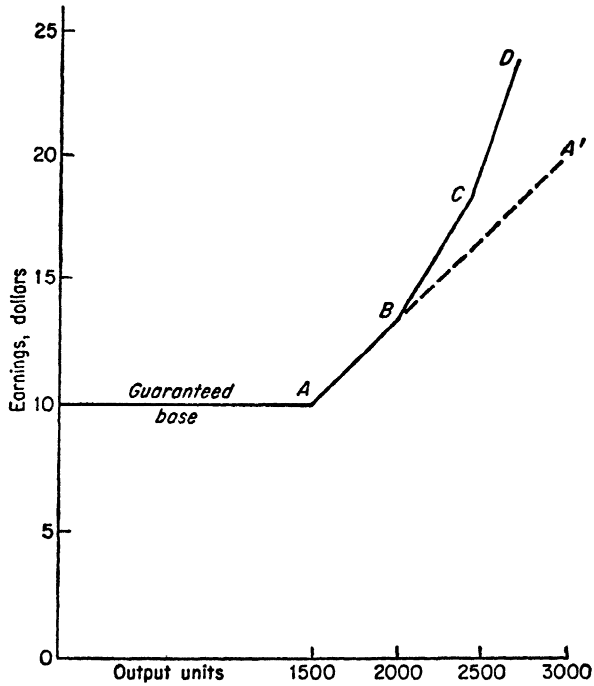
TECHNIQUE 2. Piece Rates

The logic of wage-incentive systems is most clearly expressed in the piece-rate technique. Basically, this device requires only a simple multiplication, the rate of pay being determined by the number of units produced times the rate per unit. Algebraically this can be expressed as $W = U \times Ru$, where W represents the wage earned, U equals the units produced, and Ru is the rate per unit. This equation represents the well-known straight piece rate, commonly used in industry. There are numerous variations of this plan. The most important, and currently universally applied, involves the injection of a minimum-wage guarantee in the event that the worker fails to produce a required number of units in a specified time period. Thus, on a daily basis, if the rate per unit Ru were \$0.007, then 1,429 units must be produced to yield a minimum of \$10 per day. If this sum is agreed upon as the barest minimum which a worker should earn on a specific job, then even if his output dropped to 1,300 units for a given day, his pay would be pegged at \$10. However, if he produced 2,000 units, then the compensation W would be calculated by multiplying $U \times Ru$, or $2{,}000 \times \$0.007 = \$14$. In essence, this setting of a guaranteed minimum simply means that the wage-incentive plan is inoperative until the prescribed minimum output has been attained. Up to that point, a guaranteed daily or weekly pay rate is in force. This version of piece-rate payment is shown graphically in Exhibit 18-1, as line AA'.

Among the variations of the piece-rate technique are two-step, three-step, and other multiple-step plans. One of the earliest innovations in this category was Taylor's differential piecework plan, sometimes referred to as a punitive piece rate. Taylor's plan was based upon the premise that scientific methods, and specifically motion and time studies, should be used to determine a fair day's work for which a fair day's pay would be granted. On this basis, a prescribed output expectation per hour or per day could readily be set. For example, if \$10 per day were considered an equitable pay for the production of 1,429 units of a product, then the piece rate would be computed simply as $\$10.00/1{,}429 = \$0.007$ per unit. If a worker attained the previously mentioned output of 2,000 units, then $W = U \times Ru$, or $W = 2{,}000 \times \$0.007 = \$14$. However, if an employee failed to reach the prescribed norm by producing, for example, only 1,300 units, then a second and lower rate was applied. For example, if this rate were pegged at \$0.006, then $W = U \times Ru$, or $W = 1{,}300 \times \$0.006 = \$7.80$. The objective of this punitive rate is obvious. By penalizing poor performance, Taylor believed that every worker would do his utmost to reach

at least the minimum level of the higher rate. Since company overhead costs were estimated on the basis of the prescribed minimum set for the higher rate, those who failed to meet this quota were directly responsible for increasing overhead charges. The punitive rate was thus a means by which those responsible for higher operating costs would directly pay for such costs. Any other system simply means that the more efficient workers and the other productive factors must pay for the lag of the inefficient. The logic of Taylor's plan, from

Exhibit 18-1. Piece-rate Payments



an efficiency point of view, was beyond reproach. The resistance of numerous worker groups, however, has resulted in the relegation of Taylor's differential piecework system to the inactive category.

All multiple-piece-rate plans are fundamentally similar to Taylor's plan. In practice more than two or three steps per plan results in complex calculations. On the other hand, a single or straight piece-rate plan does not take cognizance of the geometric increase in difficulty necessary to raise output, particularly after the point of diminishing returns has been reached. If two or more steps are to be used, it is possible to so set the incentive scheme that the upper rate times total

output determines the amount earned. More commonly, the several rates are applied to the respective quantities prescribed for each rate. For example, a rate of \$0.007 per unit can be set for production up to 2,000 units per day. A rate of \$0.009 per unit might apply from 2,001 to 2,500 units per day, while a rate of \$0.020 might be set for output over 2,500 units per day. This latter rate is intentionally exaggerated to emphasize the slope of the earnings line. A worker producing 2,750 units would have his pay computed as follows:

$$
\begin{aligned}
W &= (U_1 \times Ru_1) + (U_2 \times Ru_2) + (U_3 \times Ru_3) \\
&= (2{,}000 \times \$0.007) + (500 \times \$0.009) + (250 \times \$0.02) \\
&= \$14.00 + \$4.50 + \$5.00 \\
&= \$23.50
\end{aligned}
$$

This particular wage-payment scheme is shown graphically in Exhibit 18-1. The three piece rates are here labeled as lines *AB, BC,* and *CD,* respectively. It is obvious that the earnings using this three-step piece rate are considerably higher than earnings based on a straight *AA′* rate. Comparable earnings from such a single piece rate can be determined by reference to the dotted-line extension of the *AA′* rate. Actually, the three phases labeled *AB, BC,* and *CD* approximate a curve which ascends at an increasing rate. This characteristic is also found in certain of the empiric plans and specifically in the Emerson bonus efficiency plan described later. This feature, and especially if additional steps are used, gives this modification a geometric pattern which is contrary to the arithmetic proportionality generally associated with the piecework concept.

Piece rates have much to commend them. They are simple to calculate and to comprehend. Costs of installation, supervision, and record keeping are relatively low. The rank and file will more readily accept such plans. They are direct, indicating an obvious cause-effect relationship between output and pay. However, this device can be used only where such a cause-effect relationship is obvious, as, for example, where a machine operative can individually control the rate of output. Where operations are machine-paced, it is difficult to justify piece rates.

Since piece rates tend to give all the labor savings to the employee, these plans have a strong incentive value. However, this aspect necessitates precision in setting standards. Loose standards can result in excessive labor costs, while excessively rigid standards can lead to demoralization. Proper motion-and-time studies patently are important prerequisites of this technique.

Among other features of piece rates is their value in production

planning and control. The fact that direct-labor costs remain constant per unit of output facilitates accounting practice and cost estimating.

As a sort of balance to these positive aspects, it should be pointed out that piecework gives no recognition to seniority or to merit rating. Where unions are strongly entrenched, there frequently is pressure by the union to set a tacitly accepted ceiling upon the maximum permissible output. Such union-sanctioned quota setting obviously vitiates the concept of piece rates. This practice, while it is not to be condoned, sometimes has its origin in the familiar rate-cutting propensity of some unscrupulous managers. Regardless of the cause, however, the arbitrary productivity curtailing by workers who might otherwise produce considerably more is contrary to the purpose of wage-incentive systems and to the objective of sound industrial practice.

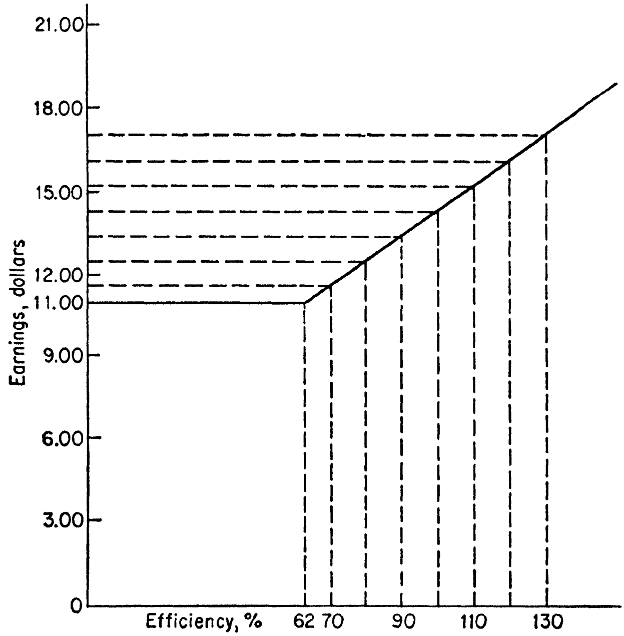
TECHNIQUE 3. The Logic of Constant Sharing

Straight piece rates generally provide for the allocation of all the labor savings to the deserving workers. Multiple piece rates frequently go even further, apportioning some or all of the overhead savings among the high-output workers. An obvious inference regarding this sort of arrangement is the recognition that work standards must be carefully set. Standards that are too tight or too loose inevitably result in serious harm. The importance of sound standards means that every job involved must be carefully studied so that the optimum sequences and times can be determined. However, in many situations such precision is unattainable. This is particularly true with new jobs, rapidly changing jobs, machine-paced operations, indirect-labor-type jobs, and cases where adequate analysis would be prohibitively costly. Caution dictates that in these instances bonus payments be conservative in character. Too frequently what initially appears to be a labor saving turns out, upon more careful analysis, to be merely a matter of grossly inaccurate cost accounting. Unless substantiated by increased productivity any "extra" unearned wage payment means either an overpriced product or an insidious subsidy of inefficiency through disinvestment of stockholders' equity. In either event, the negligent company is tobogganing into bankruptcy.

Halsey Constant Sharing Plan. This plan originally was designed for use in areas where operations were nonstandardized, where quasi standards were crudely estimated and inadequately timed, and where attempts at standardization were subject to great uncertainty because of uncontrollable variables. Halsey's suggestion of a 50–50 sharing of labor savings was, at the time of its introduction, a major innovation.

Since it was designed for jobs for which precise standards were unattainable, the equal-sharing provision seemed fair. However, as advances were made in the scientific appraisal of jobs, the incidence of guessed-at standards decreased considerably, reducing the value of this incentive plan. Among factors other than actual job timing and analysis which have modified the situation is the steadily improving flow of interindustry and intercompany information relative to job

Exhibit 18-2. Example of Halsey 50-50 Constant Sharing Plan



standards. The *Dictionary of Occupational Titles* has also been of great value. A growing number of dependable predetermined time techniques, including methods-time measurement (MTM), the Work-Factor System, etc., also facilitate the setting of fairly accurate standards where previously only custom or guesswork provided the necessary norms.

While the Halsey 50–50 constant sharing plan was designed for jobs that were not adequately time-studied, modifications of the plan are today applied successfully to any situation where the jobs are significantly affected by certain uncontrollable variables. The uncertainty of possibilities in such cases makes nonfeasible the use of most other wage-incentive techniques.

Generally, the Halsey plan sets a low-task level of 62½ per cent of high task as the bonus starting point. Thus the intermediate range from this low-task point upward provides a strong appeal to the employee to improve efficiency. However, as high task is approached, and particularly when it is surpassed, the inducement diminishes. The value of the plan, consequently, is in the intermediate range, stimulating performance from low task upward in those jobs where uncontrollable variables significantly influence operations.

Exhibit 18-2 depicts graphically the earnings and cost curves of the Halsey 50–50 plan. Exhibit 18-3 lists the pertinent figures. Even

Exhibit 18-3. Halsey 50–50 Constant-sharing-plan Data

Output per cent of standard	Efficiency based on 62½%	50% of labor savings	Base wage plus bonus, per cent	Dollar earnings on an $11-per-day base wage	Output per day in units	Labor cost per unit
62.5	100	0	100	11.00	1,250	0.00889
66	106	3	103	11.33	1,320	0.00858
70	112	6	106	11.66	1,400	0.00833
80	128	14	114	12.54	1,600	0.00784
90	144	22	122	13.42	1,800	0.00745
100	160	30	130	14.30	2,000	0.00715
110	176	38	138	15.18	2,200	0.00690
120	192	46	146	16.06	2,400	0.00669
130	208	54	154	16.94	2,600	0.00651

a casual inspection is adequate to note the differences between this plan and, for example, piece-rate systems.

The provision of a 50–50 distribution of labor savings, particularly where conditions tend to become standardized, frequently becomes inadequate. Necessity then dictates that a new formula be devised with other than a 50–50 labor-savings sharing by employer and employee. This new ratio will generally be determined by the nature of the work, the caliber of the personnel, the need for a specific type of inducement, and the inherent cost characteristics.

Hybrid Plans. There is another category of wage-incentive systems which combines the fundamentals of piece rate and time payments. The best known of these hybrid plans is the Gantt task and bonus plan, introduced in 1901. Gantt sought to ameliorate the harshness of Taylor's differential piecework plan by incorporating the high-step bonus at task with a more favorable payment for workers producing

below task. Consequently, Gantt proposed a time guarantee for such less efficient performance. This measure was very typical of Gantt, who, although adhering rigorously to most of Taylor's scientific-management precepts, disagreed strenuously with Taylor in regard to the "punitive" factor. Gantt might be said to have mollified, polished, refined, and made more palatable to the workers a number of Taylor's rather severe management concepts and techniques.

The substitution of a day guarantee for Taylor's punitive piece rate below task gives workers on certain types of jobs a feeling of security without which such work might be considered undesirable. The obvious limitation of this guarantee, the temptation for substandard workers to become complacent, can easily be counteracted by either adjusting the guarantee downward or even by substituting a constant-sharing provision in place of the guaranteed time payment. Typical of all Gantt's production-technique suggestions, the task and bonus plan was intended as a psychological device to get better performance out of workers without seemingly arbitrary demands. Gantt even went so far as to try inculcating "habits of industry" in the workers. Practically all management authorities agree that the Gantt task and bonus system is humane and has a strong financial incentive. Combined with another Gantt innovation, the standard man-hour, this plan lends itself to effective production planning and control. The man-hour as a unit of measurement, although less flexible, is more fundamental and far less arbitrary than Bedaux's *B*, described in the next section. Gantt's purpose in using the man-hour as a common denominator was to condition the workers to think in terms of amount of work rather than number of dollars.

While the Gantt task and bonus plan is not usually labeled as a sharing plan, it does serve to illustrate the logic by which the basic components of time, piece rate, and bonus can be combined. As a hybrid the plan incorporates not only some of the advantages but many of the limitations associated with the three fundamental techniques.

TECHNIQUE 4. Constant Sharing Plans with Common Denominators

Bedaux Point Premium Plan. A relatively simple modification of the constant-sharing-bonus technique was introduced during the World War I period by Charles Bedaux. Basically, his plan substituted a 75–25 sharing for the Halsey 50–50 ratio. Another important innovation was the injection of a common denominator, termed a *B*, by which all performance in the company could be equated. This standardized unit, the *B*, equals one clock minute apportioned be-

tween actual working time and permissible allowances. Obviously, the ratio of work time and allowance time varies with the nature of the specific work. However, in every instance a *B* equals exactly 1 minute. Use of such a time-unit standard evidently facilitates comparisons even among the most dissimilar types of work. There seems to be little need to stress the importance of such a common denominator for more effective production and cost control.

On the other hand, as was explained in previous chapters, the very essence of scientific time study is the determination of standard or task times. These, in turn, are invariably composites of actual work time plus legitimate delay time. Frederick Taylor, in his pioneering experiments, as shown specifically in illustrations 1 and 2, Chapter 2, emphasized the intimate correlation between the time a worker was actually "under load" and the requisite "recovery" time. He also stressed the reciprocal nature of rigor of the work and the proportion of the work day to be spent in actual performance. Recalling Taylor's contributions, it is evident that Bedaux's point premium plan is not a major new incentive technique despite its popularizing of the *B* as a common denominator for company-wide and even for universal application.

In addition to popularizing the *B* as a standard time unit, this plan originally had several other distinguishing features. The labor savings resulting from completion of a job in less than the alloted *B*'s was shared, usually, on a 75–25 basis. The larger portion was given to the employee, while the 25 per cent was pooled for subsequent distribution among indirect labor and specifically supervisors. The logic of such sharing seems obvious. However, this feature has proved to be the plan's most serious limitation. Workers, particularly on jobs where the indirect-labor and supervision aspects seem to have little bearing on individual worker productivity, have voiced strenuous objections to such sharing. These objections have led, in most instances, to the very simple expedient of eliminating the sharing feature. The result is a "modified" Bedaux plan.

The mechanics of the basic Bedaux plan are very simple. After careful analysis by proper work-measurement techniques, a specified portion of each *B*, varying from $\frac{1}{3}$ to $\frac{9}{10}$, is considered as actual working time. The remainder constitutes a composite allowance for fatigue, personal matters, machine breakdowns, etc. Each job, after study, is assigned a designated number of *B*'s. This constitutes the standard. Comparison of actual performance time with allowed *B*'s yields an efficiency ratio by means of which earnings can be computed. Up to 100 per cent efficiency, the employee receives a guaranteed

hourly or daily rate. Beyond 100 per cent, under the original plan, the worker would get 75 per cent of the time saved multiplied by the hourly rate. The remaining 25 per cent would be pooled for subsequent distribution among indirect-labor components. Since the Bedaux plan was modified, the entire labor savings now is given the responsible employee.

As an example, if a specific job rated at 240 *B*'s were completed in 180 minutes, then the responsible individual has, in effect, completed a 4-hour task in 3 hours. Under the original Bedaux plan his wages would be computed as follows: $W = H_aR_h + 0.75(H_s - H_a)R_h$. In this equation H_a, H_s, and R_h refer to actual hours, standard hours, and rate per hour, respectively. If R_h has been set at $2 per hour, then

$$\begin{aligned} W &= (3)(2) + 0.75(4 - 3)(2) \\ &= 6 + 0.75(2) \\ &= \$7.50 \text{ for this specific job} \end{aligned}$$

At this rate the individual is earning $2.50 per hour, or $20 per 8-hour day.

Using the modified Bedaux plan, $W = H_aR_h + 1.00(H_s - H_a)R_h$. In this instance $W = \$8$ for the particular job.

Among this plan's most commendable features is its usefulness for production control purposes. The *B* as a common denominator permits intra- and interdepartmental comparisons. Planning and scheduling are facilitated. Unfortunately, if very stringent precautions are not adopted, this reduction of many unlike activities to the supposedly simple common denominator can result in serious misunderstanding. This has been the case in quite a few instances where there was too hurried an adoption of the plan without proper consideration of job improvements. The Bedaux plan, when improperly applied, particularly in its man-rating aspects, has led to charges by organized labor that it is a device for ultimate speed-up and rate cutting.

The plan has other limitations, including excessively high clerical costs. It is most suited for plants having relatively standard operations that have been carefully studied. Its complexity requires careful explanation to all participants. This complexity, among other characteristics, makes the plan more usable in large concerns, particularly those with strong centralized management and with widely diversified operations.

Other Point Techniques. The Haynes Manit premium plan is probably the second best known of the constant-sharing-point plans. It resembles the Bedaux plan in its use of the minute as a standard unit. The term *Manit* is simply a contraction of the term *man-minute.*

The standard number of Manits is determined by time studies, with proper adjustments being made for normal efficiency. Pay rates are set per hundred Manits. These rates vary depending upon class of work, efficiency, and length of service.

In the original plan, when used in unstandardized industries where task levels were low and uneven, the labor savings were shared by the responsible employee, his supervisors, and the company in a 5:1:4 ratio. This distribution was modified for standardized activities so that the employee received five-sixths and the supervisors one-sixth of the labor saving. Subsequently, the plan was modified to give all the labor saving to the worker. This modification means that this technique became simply another version of basic piece-rate payment except that standards and calculations are made on a basis of minute units of time. The Manit, then, like Bedaux's *B*, is simply a clock minute comprised of a measured amount of productive time plus legitimate time allowances. This basic division of the clock minute into productive and nonproductive portions has also been used in a number of similar plans, none of which has become widely accepted.

TECHNIQUE 5. Variable Sharing Plans

Emerson Efficiency Bonus. Harrington Emerson's plan, despite its seeming complexity, is one of the very earliest contributions in the field of wage incentives. Emerson, as a pioneer proponent of scientific management, sought to correct the deficiencies of piece-rate methods by using an empiric scale of earnings, determined by a scientifically calculated sequence of efficiencies. The term *empiric* in this context refers to the foundation of the technique in experience, records, and facts. The empiric approach is sometimes also referred to as the experimental method.

The basic differentiating feature of the Emerson plan is its use of a steadily increasing bonus percentage, beginning with a very small bonus (0.01 per cent of base wage) at 67 per cent efficiency. The bonus becomes progressively bigger, equaling 2 per cent at 77 per cent efficiency, 10 per cent at 90 per cent efficiency, and 20 per cent at 100 per cent efficiency. Above this high task, increments of 1 per cent bonus for every additional 1 per cent efficiency are provided. In contrast to piece rates and constant sharing plans which maintain an arithmetic relationship between earnings and performance, the empiric technique provides a geometric progression. The most commonly used formula for this empiric plan has $W = (1 + B)H_aR_h$, where H_a is the actual number of hours on the job, R_h is the hourly rate of pay, and $(1 + B)$ is a factor comprising the base plus the bonus in

percentage terms. Thus, at 90 per cent efficiency, an 8-hour job at \$2 per hour yields:

$$\begin{aligned} W &= (1.00 + 0.10)(8)(2) \\ &= (1.10)(16) \\ &= \$17.60 \end{aligned}$$

The stress on the efficiency factor means that adequate records must be maintained. While such record keeping has obvious merits, it does increase costs and complicates the control process. Accurate calculation of efficiency also requires reliable methods analysis and time study. This is counter to the generally accepted view that bonus plans, which begin below high task, do not require accurate motion-and-time study.

While the empiric type of plan, with its geometric bonus progression, exerts a powerful inducement upon most workers, stimulating them to attain the upper efficiency levels, the technique also has some serious limitations. Record keeping and computational work, as previously mentioned, is considerably increased. The average worker generally has difficulty in interpreting the technique. Then too, the increment at the lower levels is so insignificant that very often the hoped-for motivation does not materialize. The reason for this limitation is apparent from an inspection of columns 1 and 3 in Exhibit 18-5. An efficiency gain from 66 to 80 per cent is accompanied by a mere 39 cents bonus. On a \$12 base rate, such a premium is very insignificant. However, as efficiency approaches and exceeds high task (100 per cent), the bonus becomes far more attractive. Consequently, it is assumed that every worker with requisite ability will strive to attain high task.

Exhibit 18-4. Emerson Efficiency Bonus Scale

Efficiency as per cent of high task	Bonus as per cent of base wage
66 and less	Hourly rate, no bonus
67	0.01
70	0.22
75	1.31
80	3.27
85	6.17
90	9.91
95	14.53
100	20.00

Increments of 1 per cent bonus for each extra 1 per cent efficiency after reaching high task.

Exhibit 18-4 lists several of the Emerson efficiency bonus plan's performance-earnings relationships. Only selected efficiency levels have been listed. However, this sample listing should be adequate to demonstrate the very low initial bonus at 67 per cent of standard, the geometric progression from the beginning point up to the high-task level (100 per cent), and, finally, the proportionate 1 per cent increment in performance and bonus beyond the high-task level.

Exhibit 18-5 indicates the procedure by which daily earnings can be calculated. Column 3 is simply a translation of the base rate, in this instance an assumed $12, into the base rate plus bonus which constitutes actual earnings. For example, at 90 per cent efficiency, the Emerson plan provides for a base wage plus bonus payment equaling

Exhibit 18-5. Example of Emerson Efficiency Bonus Plan

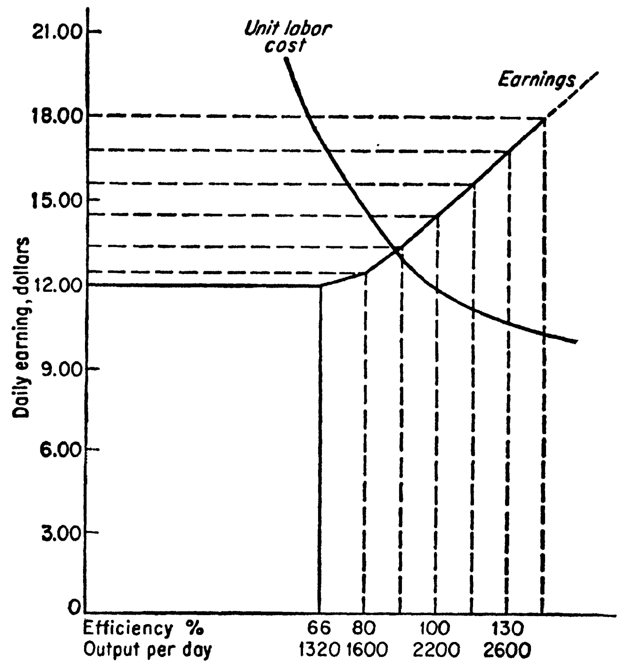
(1) Efficiency	(2) Base wage plus bonus	(3) Earnings	(4) Output per day in units	(5) Labor cost per unit
66	100.00	12.00	1,320	0.00909
70	100.22	12.03	1,400	0.00860
80	103.27	12.39	1,600	0.00775
90	109.91	13.19	1,800	0.00733
100	120.00	14.40	2,000	0.00720
110	130.00	15.60	2,200	0.00709
120	140.00	16.80	2,400	0.00700
130	150.00	18.00	2,600	0.00692

109.91 per cent of the guaranteed daily rate. In this case, the actual earnings total $13.19. Similarly, the provision of 120 per cent payment of base rate at 100 per cent efficiency results in earnings of $14.40.

Once total earnings have been computed, it is a simple procedure to determine the labor cost per unit of output. These figures can be obtained by dividing column 4, the total output per day, into column 3, total earnings. Labor costs per unit of output, as shown in column 5, tend to decrease under the Emerson plan, but at a steadily decreasing rate. For example, the absolute unit decrease in unit labor costs between 70 and 80 per cent efficiency equals $0.00085. Similar savings dwindle to only $0.00042 for the 80 to 90 per cent bracket and to a mere $0.00008 for the 120 to 130 per cent efficiency levels. This unit-labor-cost pattern is, obviously, very different from the unit-labor-cost relationship prevailing in piece-rate and in constant sharing systems. This specific feature is sometimes singled out as being the Emerson plan's prime negative factor.

Other Empiric Plans. There are a number of variations of this pioneer empiric plan. Among the best known is the Wennerlund bonus plan, introduced by one of Emerson's associates, who adapted this type of bonus system for a number of General Motors plants. The Wennerlund, or the "Olds," plan is very similar to the Emerson plan except that it starts at 75 per cent of high task. The bonus increments between the starting point and high task are somewhat higher than in

Exhibit 18-6. Emerson Efficiency Bonus Plan



the Emerson plan. In this respect it is a distinct improvement since the incidence of relatively insignificant bonus payments is reduced. For all practical purposes, despite some modifications in technique, the Wennerlund plan has virtually all the advantages and limitations of the Emerson plan.

Other well-known modifications of the Emerson plan include a rather broad category referred to as empiric plans with step bonuses. An example of this group is the Knoeppel efficiency bonus plan. Practically the only difference between this and the Emerson plan, both of which begin at 67 per cent efficiency, is the injection of a 5 per cent bonus when the worker attains 100 per cent of high task. Obviously, this step increment should serve as a powerful inducement

for every qualified worker to exceed the point where the step bonus occurs.

Similar minor differences distinguish the Allingham, Atkinson, Bigelow, Bigelow-Knoeppel, Parkhurst differential and various other related empiric plans. The last, for example, provides for bonus inception at either 60 or 70 per cent of high task. In addition, the plan sets up 15 classes of work, each of which has a different bonus schedule. Rather elaborate tables are available showing detailed calculations of bonuses for varying efficiencies and for all the different classes.

Special slide rules have been designed for use in all the empiric devices. These slide rules enable the timekeeper to make rapid comparisons between standard hours and actual hours. After such calculations have been made, reference to the bonus chart permits very rapid determination of individual or group earnings.

SUMMARY

While there are numerous variants of the basic wage-incentive techniques, there is a common procedure which should be followed in every instance. The recommended steps include:

1. Recognition of the need for incentive motivation
2. Getting worker and, if feasible, union support for the general principle and also for the specific plan
3. Properly explaining the purpose and mechanics of the plan
4. Securing agreement as to best type of incentive for company's needs
5. Gearing, in conjunction with step 4, the plan to an increasing, a decreasing, or a constant share of the labor savings
6. Setting suitable standards of performance
7. Adapting the incentive system to normal output of the average qualified jobholder
8. Providing a guaranteed minimum wage consistent with legal aspects, skill requirement, and wage patterns in the specific industry and area
9. Anchoring the plan to a gain in earnings within the customarily accepted 15 to 30 per cent range
10. Reviewing the plan periodically and making modifications when deemed necessary

ILLUSTRATION 1. Incentive Pay for Indirect Labor[1]

Reference has been made to the serious limitations frequently encountered in the application of incentive systems where:

[1] Adapted from D. H. Denholm, "Newest Way to Avoid Downtime," *Factory Management and Maintenance*, vol. 114, no. 4, McGraw-Hill Publishing Company, Inc., New York, April, 1956, pp. 88–89.

1. The operations are machine paced.
2. It is difficult to attribute production specifically to an individual or an easily identifiable group.
3. The rate of output is significantly influenced by the contribution of indirect labor.

The latter limitation in particular has posed many complex problems for industrial administrators. The following is an example of how, in one specific instance, this perplexing problem has been approached with notable success. A bonus system for some of its indirect labor was installed by the Chase Bag Company of St. Louis, Missouri, in two of its four plants. This particular bonus plan covers a rather wide range of indirect labor, including loom fixers, whose basic function is keeping the regular and the Leno looms used in these plants properly maintained and in optimum operating condition. Within two years after the installation, the effectiveness of this particular plan was demonstrated by an increase from 90 to 95 per cent in loom efficiency, accompanied by a 10 per cent increase in average take-home pay.

Loom fixers comprise about 20 per cent of the labor force in the company's two plants using this incentive system. If two other closely related categories of indirect labor, filling distributors and roll changers, are added, then this group would include nearly one-third of the work force. For purposes of identification, filling distributors are concerned with carrying bobbins to the looms, while roll changers take the finished rolls from the looms to storage.

The bonus system uses a formula derived from a six-month average of efficiency in the plant prior to the plan's installation. This formula is compared with the loom room's efficiency computed at the end of each week. For each percentage-point improvement over base efficiency loom fixers receive 1.8 per cent (3 cents per hour) extra pay.

In every instance where incentive techniques are to be used, before relative efficiency can be determined it is necessary to standardize certain important variables. In this case the standard conditions imposed included a norm for loom speed of 160 picks per minute for regular looms and 150 picks per minute on Leno looms. Ten regular looms or eight Leno looms per weaver is considered a standard work assignment. Three loom fixers, one filling distributor, and one roll man are considered adequate for maintaining 100 looms. Obviously, changes in these accepted constants would necessitate modifications in the formula.

In the calculation of the base efficiency, the 90 per cent and 88 per cent figures in the numerator refer to the average efficiency for regular

and Leno looms, respectively, during the six-month base period. The formula used in this instance states that:

$$(1)\quad \text{Base efficiency} = \frac{\text{regular loom-hours } (90\%) + \text{Leno loom-hours } (88\%)}{\text{total loom hours}}$$

In one specific instance of application the records for a two-week period showed that a particular loom-fixer group serviced 30 regular and 70 Leno looms. For these two 40-hour shifts total loom-hours would be calculated as follows:

$$\begin{aligned} 30 \text{ regular looms} \times 2 \text{ shifts} \times 40 \text{ hours} &= 2{,}400 \text{ hours} \\ 70 \text{ Leno looms} \times 2 \text{ shifts} \times 40 \text{ hours} &= 5{,}600 \text{ hours} \\ \text{Total loom-hours} &= 8{,}000 \end{aligned}$$

Applying these figures to equation 1, the base efficiency formula, results in

$$(2)\qquad \text{Base efficiency} = \frac{(2{,}400)(0.90) + (5{,}600)(0.88)}{8{,}000} = 88.6\%$$

In the actual calculation of a specific week's efficiency another formula is used:

$$(3)\quad \text{Actual efficiency} = \frac{\text{total picks} + \text{allowances}}{(\text{regular loom-hours})(9{,}600) + (\text{Leno loom-hours})(9{,}000)}$$

Obviously, records of actual production must be available to determine the work performed in terms of picks. In this example, records indicated a total of 68,016,960 picks in the two weeks being studied. The proper allowances which must be included in the numerator of equation 3 were determined, in this case, by the following procedure:

Allowances:

1. Looms down

$$\begin{aligned} 5 \text{ regular looms for one 8-hour shift} &= 345{,}600 \text{ picks lost} \\ 8 \text{ Leno looms for one 8-hour shift} &= 506{,}880 \text{ picks lost} \end{aligned}$$

2. Changeover

$$\begin{aligned} 8 \text{ regular loom-hours lost} &= 69{,}120 \text{ picks lost} \\ 12 \text{ Leno loom-hours lost} &= 95{,}040 \text{ picks lost} \\ \text{Total allowances} &= 1{,}016{,}640 \text{ picks lost} \end{aligned}$$

These allowances were determined by multiplying standard picks per minute times the number of minutes times the efficiency factor.

Thus, for regular looms, $160 \times 60 \times 90\% = 8{,}640$ picks per hour. The looms-down allowance for 5 regular looms for one 8-hour shift would be computed by multiplying $5 \times 8 \times 8{,}640$, which equals the 345,600 picks lost as listed above. Similarly, the Leno loom down time was derived by multiplying 150 picks per minute $\times$ 60 $\times$ 0.88, which equals 7,920 picks per hour. The 8 Leno looms idle for one 8-hour shift would give an allowance of $8 \times 8 \times 7{,}920$, or 506,880 picks lost. The changeover allowances are computed in a similar fashion.

The next step in this analysis is the insertion of the actual figures in equation 3 so that:

$$(4)\quad \text{Actual efficiency} = \frac{68{,}016{,}960 + 1{,}016{,}640}{(2{,}400 \times 9{,}600) + (5{,}600 \times 9{,}000)} = 94\%$$

This is the two weeks' efficiency in terms of the optimum. The actual efficiency (equation 4) must then be compared with the base efficiency (equation 2) as observed during the six-month period which formed the basis for the incentive plan. During the base period average performance = 88.6 per cent. Thus the current 94 per cent is 5.4 percentage points better than the test-period average. Since the incentive plan provides for a bonus of 1.8 per cent for each percentage point that the weekly efficiency exceeds base efficiency, then

$$5.4 \times 1.8 = 9.72\% \text{ bonus}$$

QUESTIONS

1. Assuming that technological changes occurred which necessitated a revision of regular and Leno loom standards to 200 and 170 picks per minute, respectively, how would the calculations in this example be affected? To facilitate your calculations, assume that the base efficiency remains constant and the new total of actual picks for a given two-week period equals 84,380,000.

a. What is the new actual efficiency and the new bonus percentage?

b. What recommendations would you suggest?

c. What are the old and the new rated capacities in terms of maximum picks per week?

d. Which of the techniques described in this chapter does this wage-incentive plan resemble?

e. In what respects is this situation atypical as an indirect-labor wage-incentive plan?

ILLUSTRATION 2. A General Wage-payment Formula

Formulas generally associated with wage-incentive systems are intended to perform the function of translating a given worker's performance on a given job into value terms. These formulas obviously are very useful since they provide an objective means for making decisions in an area where subjective factors seem to predominate.

However, of even greater significance than the simple calculation of pay in dollars and cents is the logic inherent in this type of algebraic presentation. Fundamentally, a wage-payment formula should give proper weight to the factors of time, effort, ability, job differentials, and minimum legal or subsistence wage levels. These factors are variables whose values are sometimes determined arbitrarily, sometimes by circumstance, and on occasion by scientific measurement. It should be evident that the subjective aspects affecting these factors make precise measurement rather tenuous. For example, even though physical effort might be converted into a norm such as foot-pounds, there is considerable doubt that such a yardstick is adequate for managerial control purposes. Measurement of mental effort would be an even more controversial matter. Consequently, this formula is presented merely as a succinct and logical illustration of how wages should be determined, at least in theory, and in practice to the degree that reliable quantification is feasible. In this instance, letters of the Greek alphabet have been used as symbols for the various terms merely as an attempt to acquaint the student with this technique of symbolization. Actually, any set of symbols, properly defined, could be used for this purpose. In this particular formula the pertinent symbols and terms are as follows:

ϕ = earnings
α = time worked
β = extra effort expended
γ = extra ability applied
δ = minimum legal or subsistence wage
ϵ = job differential for difficulty
η = job differential for tenure and seniority

The formula in an equitable pay system could then be expressed as:

$$\phi = \alpha\sqrt{\beta \times \gamma}(\delta + \epsilon + \eta)$$

The $(\delta + \epsilon + \eta)$ portion of the equation simply means that every job should be assigned a pay rate reflecting the differentials for relative difficulty and for seniority, added to the minimum pay made mandatory by law, custom, or subsistence requirements. The radical $\sqrt{\beta \times \gamma}$ injects the elements of extra effort and extra ability. In effect, this is the critical aspect of every incentive system. If average expenditure of effort and of ability is assigned values of unity, or 1, then proportionate increases in application of either or both effort and ability will raise this multiplier. Conversely, less effort or use of a less qualified

person will lower this figure. Very obviously the relative expenditure of effort and the relative level of ability possessed by an individual are difficult to measure. Invariably sound judgment is required to quantify these factors. The final item in this equation, the influence of time upon earnings, should be apparent.

The following is a simple illustration of this generalized formula. In this case it is assumed that minimum wage laws prescribe a floor of $1 per hour and that the particular job-evaluation technique ascribes a differential of $1.25 to a specific job. Seniority or automatic pay increases have added $0.25 to base pay. The effort expended by the individual is equated at 0.8 of normal. His ability, however, is measured at 1.5 of normal. In both these judgments, as to the man's expenditure of effort and his level of ability, it must be stressed that the numerical designation probably should not follow a rigid arithmetic progression.

The final phase in building this logical structure of wage components in equation form consists in multiplying by the time factor. The result should theoretically show wages proportionate to the product of the various components included in the formula. Thus $\phi = \alpha\sqrt{\beta \times \gamma}(\delta + \epsilon + \eta)$. If the results show inequality rather than equality, then the sign $=$ becomes either $>$ or $<$. In the former, the symbol $>$ indicates that wages are disproportionately high; thus equity tends to become privilege. If the "less than" symbol $<$ is appropriate, then equity tends to approximate exploitation. In either of these extremes disequilibrium enters into the wage structure.

QUESTIONS

1. Does this formula take into account all important variables affecting wage determination?
2. How does this formula relate to the capacity and power factors discussed in Part One?
3. How would you evaluate the following three cases?

	(1)	(2)	(3)
$\phi =$	$16.00	$16.00	$16.00
$\alpha =$	8.00 hr	6.00 hr	8.00 hr
$\beta =$	1.10%	1.20%	0.85%
$\gamma =$	1.10%	0.80%	0.60%
$\delta =$	$1.00	$1.00	$1.00
$\epsilon =$	$0.90	$1.40	$0.70
$\eta =$	$0.20	$0.30	$0.40

ILLUSTRATION 3. Ralston Purina Bonus Plan[2]

Many incentive plans focus undue attention upon man productivity and overlook the significance of factors such as machine potential, availability of materials, etc. The Ralston Purina bonus plan for operators takes into account the fact that machine-attendance time is generally constant per machine operating time for a given machine.

Exhibit 18-7. Portion of a Standard Sheet, Ralston Purina Company

Elements of operation	Symbol	(1) Standard man-hours per occurrence	(2) Frequency factor	(3) Standard man-hours per machine operating hour
Machine operation:				
Visually inspect operation of individual machine; make minor adjustments. Check flow of material to and from.	A	0.060	4 per hour	0.240
Recording:				
Check and record ammeter and productometer readings.	B	0.021	2 per hour	0.042
Sample:				
Take samples of material to machine and product from machine. Check against specs. Dispose of samples	C	0.040	4 per hour	0.160
Capacity test:				
Run test on machine. Weigh, record, dispose of each capacity sample.	D	0.055	1 per hour	0.055
Total use				0.497 (0.500)

SOURCE: Eric A. Carlson, "Bonus Plan for Machine Operators," *Factory Maintenance and Management*, vol. 115, no. 3, pp. 104–106, March, 1957.

This means that stress is placed upon a factor which tends to remain constant despite fluctuations in the output rate. The company has, consequently, devised a production-effectiveness ratio which is simply the ratio of actual machine output per operating hour to the standard

[2] Adapted from Eric A. Carlson, "Bonus Plan for Machine Operators," *Factory Maintenance and Management*, vol. 115, no. 3, pp. 104–106, March, 1957.

machine capacity per machine operating hour. An operator's efforts are effective only to the degree that he can utilize the machine's capacity at the rate prescribed for that machine. An operator putting forth more units than the standard, as set for a specific machine, obviously is proportionately more effective. His production-effectiveness ratio reflects this positive feature since, in this case, it will be higher than unity, or 100 per cent. Less than standard performance similarly earns proportionate ratios below the 100 per cent level.

Exhibit 18-7 shows how operators' duties are classified into four elements: machine operation, recording, sampling, and capacity testing. Time study or, where preferable, standard data are used to set individual standards for one occurrence of each element. Since these elements are rather general, adequate provision for fatigue and personal allowances should be included in the standard times listed in column 1. A frequency factor must be set for each element per machine operating hour. Observation, tempered by experience, is the best source of these frequency factors shown in column 2.

The next step is obvious. Multiplying the corresponding figures in

Exhibit 18-8. Example of a Daily Man-hour Analysis

Operation	Unit of measure	(1) Production	(2) Standard man-hours allowed	(3) Standard man-hours produced	(4) Actual man-hours
1. Operate machines 1 and 2, 1st floor, Bldg. A.	Per machine operating hour	14	0.45	6.30	
2. *Constant per product:* Change over machines 1 and 2 for change of product size.	Per occurrence per machine	2	0.50	1.00	
3. *Machine cleaning:* Brush off and wipe down machines 1 and 2 at end of shift.	Per machine per occurrence	2	0.25	0.50	
Total				7.80	8.00

Computation (column 2, item 1):

Standard (from worksheet) × production effectiveness × quality

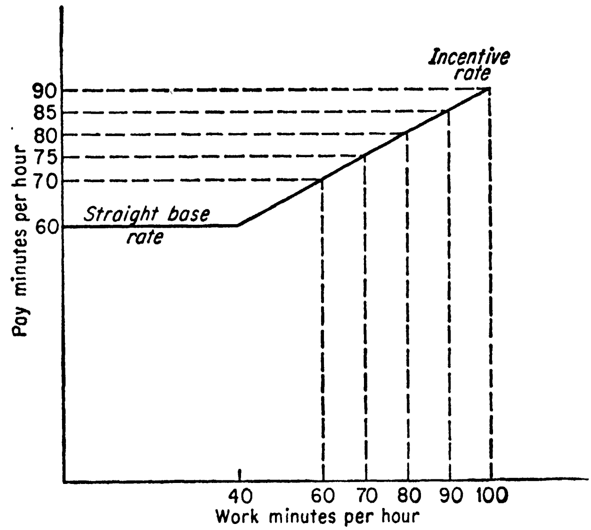
= standard man-hours allowed per machine operating hour

$$0.50 \times \frac{90}{100} \times 1.00 = 0.45$$

columns 1 and 2 yields the standard man-hours per machine as shown in column 3. The total of the figures in column 3, in this case 0.500, means that the operator should spend 50 per cent of his time per operating hour on each machine. Although such an ideal balance is not always attainable, this stress on the objective helps to maximize utilization of equipment and to equalize work loads.

In the Ralston Purina plan incentive opportunities start at 67 per cent of standard. In other words, an employee who averages 40 work minutes per clock hour is eligible for bonus payments. Exhibit 18-8

Exhibit 18-9. Ralston Purina Wage Curve



SOURCE: Eric A. Carlson, "Bonus Plan for Machine Operators," *Factory Maintenance and Management*, vol. 115, no. 3, pp. 104–106, March, 1957.

provides an illustration of how this technique operates. The employee tending machines 1 and 2 accumulated a total of 14 hours on a particular shift. Multiplying these 14 hours by the 0.45 standard hour allowed yields a total of 6.30 standard hours produced. Adding the 1.00- and 0.50-hour figures in lines 2 and 3, which cover setup and cleaning allowances, respectively, gives 7.80 standard hours earned.

The 0.45 rate used in these computations was determined by multiplying the 0.50 standard, as shown on the standards sheet, by the production effectiveness, in this case 90 per cent. The quality factor set at 1.00 does not change these specific computations.

QUESTIONS

1. Does this plan conform to the basic principles of wage-incentive payment described in the previous sections?
2. Is the production-effectiveness idea sound?
3. How might the graph be made more meaningful?

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CHAPTER 19

Synthesis: Theory and Technique

Stress has been placed throughout this text upon the vital need for a juncture and an integration of the seemingly divergent theoretical and practical approaches to leadership in industry. One of the basic premises of the text is the firm conviction that education for business administration should not be exclusively vocational in orientation. This premise follows from the belief that the longer-established and better-entrenched humanities and social-science courses do not have a monopoly upon the "thought" aspects pertinent to the study of business and industry. Philosophical consideration, together with cultural and ethical appraisal, is equally the province of business-administration courses. Just as the liberal-arts disciplines evolved during the past several centuries out of philosophy, the Queen of Sciences, so too there is today a noticeable transition in the field of learning pertinent to the administration and operation of business and industrial enterprises. This evolution has been recognized in other than the business sphere. Programs in the fields of industrial sociology, industrial psychology, communications, business ethics, industrial engineering, applied economics, and other peripheral areas are symptomatic of the need for broadening and deepening the fields of study related to industrial management.

In a dynamic world the forces of circumstance constantly create new

complexities and new problems. These must be resolved with a minimum of friction and a maximum of satisfaction. The resolution of these problems is the basic function of administrators. In turn, these administrators must operate within an organizational framework, using the best available technical tools and always striving to attain the loftiest goals set by and for the organization. The comprehension in detail, acceptance in entirety, and application with dispatch and zeal of the best techniques, together with the soundest principles, are most conducive to success in any area of endeavor, including industrial administration.

When the best techniques and theories are accepted and applied, it is safe to postulate that contrary to the logical and universally accepted premise that "the whole is equal to the sum of its parts," we can conclude that the sum of organized endeavor should be in excess of the sum of individual contributions. To recapitulate what has already been emphasized, assuming that in a specific case items a, b, c, d, and e are each equal to x, then the summation of $a + b + c + d + e < 5x$, if the organization is effective. The greater the excess of the product over the sum of individual potential and contribution, the better is that organization.

Any attempt to stress in detail the interrelationship and importance of both theories and techniques would necessarily be repetitious of what has already been analyzed in the preceding eighteen chapters. However, it might be beneficial as a final attempt at emphasis to set forth in summary form some of the basic tenets of organization and leadership. Although this recapitulation might seem trite and even replete with clichés, it does contain the essentials of sound organization.

SEVEN POSTULATES AS TO ORGANIZATION

1. The evolutionary process makes no exceptions of living beings, organisms, and even of institutions. "Adapt or perish" is equally applicable to beings, things, and organizations.
2. The rate and process of organizational adaptation is directly correlated to the caliber of the group's leadership.
3. There can be no organization without a definite, promulgated, accepted, and desired ultimate goal.
4. The means used to attain both the ultimate goal and the immediate objectives must be legitimate and the best available.
5. An organization must have symmetry in the arrangement of positions, with each position being ascribed rigidly defined rights and responsibilities.

6. Hierarchical rank demands proportionate and equitable compensation and prestige.

7. A sound structure is only a means to an end; it is no guarantee of success.

SEVEN POSTULATES ON FUNCTIONS AND LEADERSHIP

1. Functions are determined by objectives. Every member of an organization must be assigned specific rights and duties compatible with his position.

2. Delegation of authority is of vital consequence to effective organization; *but* delegation should never result in abdication of ultimate authority or responsibility.

3. Leadership is the strategic factor in every organization. While difficult to define, leadership seems to be a complex composite of aspiration, inspiration, dedication, tenacity, persuasiveness, and technical competency.

4. Leadership is not an absolute, immutable, metaphysical concept. Differences in organizational structure, in function, in group attitudes, and in the force of circumstance will dictate the type of leader best suited to the situation. The leader might be a persuader, a compromiser, a dictator, a visionary, an elder, a supertechnician, or a composite of these and other attributes.

5. There is no substitute for individual leadership. Committees, senates, opinion polls, balloting, and similar media for expressing group sentiment can be of great assistance to the decision maker. In industry, however, there is, invariably, an individual administrator who must bear the onus of initiating, promulgating, enforcing, and evaluating every important course of action.

6. Functioning both as technician and tactician, the leader must apply periodic therapy and occasional cathartics to the corporate body. Out of such corrective action comes self-improvement and organizational effectiveness.

7. Among the most important considerations in modern, successful industrial decision making are the following:

a. Objectivity in aims and means

b. Quantification of factors and results

c. Measured probability of success

d. Rigid control of actions and accomplishments

e. Mutuality of the members' interests, the leader's aspirations, and the organization's objectives

f. Equity between individual contribution and individual reward

g. A "blessed discontent" which relentlessly drives the leader and his group to newer and loftier ventures

When these and related precepts are fully comprehended and diligently applied, the organization is well on its way to success. However, it is extremely important to remember that in a competitive climate there is always the probability that other individuals and organizations are equally or even more aware of the need for the soundest organization principles and the best operational techniques. Thus attainment and satisfaction become relative. That group whose leaders are most alert and most able will have the significant advantage. The combination of zealous group members, a sound organization structure, a laudable and desirable goal, a good philosophy and related principles, together with a dynamic and competent leadership, is *invincible.*

Work with good tools. Some seek to exhibit their cleverness by pointing to the poor qualities of their tools: a dangerous type of self-satisfaction to be followed by stiff punishment. The excellence of a servant has never dulled the splendor of the master: for all the glory of what is accomplished later descends upon the first cause, as, in reverse, all the disgrace. Fame walks only with principals; she never says: this one had a good subordinate and that one, a bad; but only: this one did well, and that one did poorly. Hence, choose well, make study, for thereon depends the immortality of your reputation.[1]

SELECTED READINGS. Part II. General

Books

Alford, L. P., and J. R. Bangs (eds.): *Production Handbook,* The Ronald Press Company, New York, 1955.

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Anderson, A. C., M. J. Mandeville, and J. M. Anderson: *Industrial Management,* The Ronald Press Company, New York, 1942.

Balderston, C. C., R. B. Brecht, V. S. Karabasz, and R. J. Riddle: *Management of an Enterprise,* 2d ed., Prentice-Hall, Inc., Englewood Cliffs, N.J., 1949.

Bethel, L. L., F. S. Atwater, G. H. E. Smith, and H. A. Stackman: *Industrial Organization,* 3d ed., McGraw-Hill Book Company, Inc., New York, 1956.

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Ireson, W. G., and E. L. Grant (eds.): *Handbook of Industrial Engineering and Management,* Prentice-Hall, Inc., Englewood Cliffs, N.J., 1955.

[1] Gracian, quoted from *Let's Go,* no. 20, p. 2, August, 1958.

Maynard, H. B. (ed.): *Industrial Engineering Handbook,* McGraw-Hill Book Company, Inc., New York, 1956.

Moore, Franklin: *Manufacturing Management,* Richard D. Irwin, Inc., Homewood, Ill., 1955.

Rautenstrauch, W., and R. Villers: *The Economics of Industrial Management,* Funk & Wagnalls Company, New York, 1949.

Spriegel, W. R., and R. H. Lansburgh: *Industrial Management,* 5th ed., John Wiley & Sons, Inc., New York, 1955.

Periodicals

Advanced Management, Society for the Advancement of Management, New York (quarterly).

American Business, Dartnell Publications, Inc., Chicago (monthly).

Barron's National Financial Weekly, New York (weekly).

Business Week, McGraw-Hill Publishing Company, Inc., New York (weekly).

Dun's Review and Modern Industry, Dun and Bradstreet Publishing Corporation, New York (monthly).

Factory Management and Maintenance, McGraw-Hill Publishing Company, Inc., New York (monthly).

Forbes Magazine of Business and Finance, New York (semimonthly).

Fortune, Time, Inc., New York (monthly).

Harvard Business Review, Harvard University, Graduate School of Business Administration, Cambridge, Mass. (bimonthly).

Journal of Business, University of Chicago, Chicago (quarterly).

Mill and Factory, Conover-Nast Publications, New York (monthly).

Modern Industry, Magazines of Industry, Inc., Bristol, Conn. (monthly).

Modern Management, Society for the Advancement of Management, New York (eight times a year).

Personnel, American Management Association, New York (bimonthly).

Personnel Administrator, American Society for Personnel Administration, Toledo, Ohio (bimonthly).

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